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Dynamic Traffic Management Systems on A4 Motorways

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ABSTRACT
The A4 Motorway is the key transport connection in southern Poland and carries domestic and international traffic in the east-west direction. In 2008 a traffic management system based on variable message signs (VMS) was designed for the General Directorate of National Roads and Motorways. The system covers a section of 165 km of the A4 Motorway between the interchanges Bielany (Lower Silesia) and Sośnica (Silesia).

The main purpose of the system is to ensure seamless traffic flows and road safety. Thanks to the application of VMS and a dynamic transfer of data and information the functions of the system include traffic control, speed management, alternative route guidance, traffic information and weather warnings. The design stage of the system included the mapping of data sources, grouping of potential traffic incidents, development of message signs, setting out of actuation procedures and sequences of message display as well as outlining of communications procedures and decision making process by the administrator of the system. A lot of attention was given to factors providing for reliability of the system and credibility of messages.

KEYWORDS: traffic management system, variable message signs, traffic control, speed management, road safety

The currently used Intelligent Transport Systems (ITS) serve several functions: from warnings about potential accidents to advanced traffic management and control, using such means as changeable message signs (VMS). Long-lasting studies in American and Canadian agglomerations have shown that using such systems may decrease the infrastructural costs by as much as 20-35% and yield the same system effectiveness [1] [2]. This has also been proven by European studies [3]. These systems can be used in urban streets as well as in expressways and motorways.

The General Directorate for National Roads and Highways has launched a traffic management system in a 165-km section of the A4 motorway (Wrocław-Gliwice), i.e. from the “Bielany” node (dolnośląskie voivodeship) to the “Sośnica” node (śląskie voivodeship), fig. 1. The A4 motorway connects the border crossings at Jędrzychowice (Polish-German border) and Korczowa (Polish-Ukrainian border), and is a vital route for east- and westbound international traffic.

The nodes along the section of the A4 motorway in question now include such traffic management elements as speed-measuring stations with changeable message signs for visualising traffic parameters, as well as changeable message signs showing weather conditions. Additionally, meteorological stations and cameras were installed along the whole section included in the traffic management system. The data gathered by the system are then used for effective traffic management.

The system includes, among others:
- changeable message signs visualising traffic parameters - a total of 24 gates in both directions with VMSs, located at intersections,
- changeable message signs visualising weather parameters - a total of 23 gates in both directions with VMSs, located at intersections,
meteorological stations – 11 stations:
- forecasting (installed in places with stable surface temperatures and used for forecasting weather and surface conditions),
- supporting (located near changeable message signs, used to support weather visualisation),
- non-forecasting (installed in places, where changing weather conditions influence traffic safety, not used for forecasting),

traffic measurement stations – used to measure and register traffic parameters in real time, they detect and categorise traffic structure by vehicle type, classification according to EUR-6 [6],

- cameras at intersections,

The meteorological stations allow for measuring the following parameters of both the surface and its surroundings:
- air temperature and relative humidity,
- wind speed and direction,
- classification and intensity precipitation,
- surface and substrate temperature at 6 and 30 cm,
- surface conditions,
- amounts and concentrations of defrosting agents on the surface,
- visibility.

The road measurement stations measure and register all the parameters in real time. The parameters can be recorded in the “vehicle-by-vehicle” mode (for every vehicle), or in an aggregated form (e.g. every 5 minutes). Traffic measurement stations allow for measuring the following parameters:
- vehicle speed,
- vehicle length,

Fig. 1. The location of the A4 section included in the traffic management system
Source: [own work]
DYNAMIC TRAFFIC MANAGEMENT SYSTEMS ON A4 MOTORWAYS

• traffic category (free, restricted),
• vehicle category,
• time and date of passing the detector,
• the lane, in which the vehicle is travelling,
• time from the previous vehicle,
• distance from previous vehicle.

In the process of preparing the traffic management project, available materials as well as data provided by the devices in the system and current knowledge were used to define the main purposes for the system, groups of events and detailed procedures. Additionally, authorisations for traffic control were given to individual centres and the system for notification and decision-making was set up to control the contents of VMSs owned by the system administration.

The traffic management system may serve several different functions. Depending on the amount of changeable message signs and detectors (traffic and weather sensors), different forms of management may be employed. If the changeable message signs are located at larger intervals, the system will serve an informative and warning function. With relatively small distances (of approx. 2 km) between signs along the whole section (or in places where the signs are denser due to frequent traffic jams, adverse weather conditions or other circumstances), the system can be more effective at managing vehicle speed, gradually enforcing speed limits (which directly influences the speed at the end of the line) or managing individual lanes (by closing or opening them at certain places). The main tasks, that may be fulfilled by the ITS using changeable message signs at the A4 motorway, are:

• speed control and management achieved by levelling the speed in the traffic flow, limiting the speed (in the form of road signs or recommended driving speed), lowering the speed at the end of the queues (by warning about possible jams), lowering the speed limit due to low traffic flow or bad weather conditions,

• traffic in individual lanes may be controlled and managed by closing a lane or the whole road in incidental events (accidents, collisions) and during roadworks as well as by forcing the lorries to use the right lane only,

• traffic may be redirected to alternative routes by informing the drivers through changeable message signs about detours, traffic events (accidents, collisions), traffic overloads or other obstacles in a given section (very bad weather conditions, special vehicles),

• informing about current traffic conditions by displaying the distance and time left to main intersections, warning about exceeded speed limits, travelling too close to the previous vehicle or possible hold-ups,

• warning about weather conditions that may influence road safety by limiting the visibility (fog, intensive rainfall), lowering tyre grip (wet surface, snow or ice) or causing problems with driving straight (strong side wind).

In order for traffic control and management through changeable message signs to be as effective as expected, a lot of attention should be paid to the message being broadcast to the user, i.e. the driver, who experiences the road events directly. Therefore, the messages informing them about what happened, where it happened and how they should behave should be noticeable, readable and comprehensible. One of the factors used in creating the sequence of messages displayed on these signs was the driver’s perceptual capabilities. Due to the lack of Polish studies in this field, American studies were used among others [7].

The messages appearing on variable message signs should be brief and simple, while conveying the most information. Making the message too brief may cause misinformation. The message should not be too long either, as it may be ignored by the driver (no time to read it). Unlike the more highly developed countries, Polish literature and studies lack the principles and examples concerning the changeable message signs and the messages, that can be displayed on them.

The data provided by the devices in the ITS system along the A4 motorway are used to improve the safety of all motorists. The problem in Poland lies in the lack of such ITS elements, i.e. changeable message signs. The studies conducted along the section of A4 motorway [4] have proven that the changeable message signs impact only a small fraction of motorists. Thus, driver education should follow the introduction of warning and informative ITS devices. VMSs can also display speed limits or other prohibitory signs, that are equal in power to fixed signs, according to the act of June 20, 1997 - Traffic code (unified text in Journal of Laws no. 58 of 2003, as amended). Obviously, the changeable message signs do not replace fixed signs or temporary signs, so all of these elements should
be interconnected. The traffic management system prepared by EKKOM for the 165-km section of the motorway, which utilises, among others, the changeable message signs, is the first such solution in Poland.

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Possibilities of industrial Ethernet usage in safety critical applications

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ABSTRACT
Authors describe the possibilities of the industrial Ethernet usage in safety-critical applications as a component of safety-related control systems. The main part of the paper summarizes the safety requirements of industrial Ethernet Profinet and Ethernet/IP based on ProfiSafe and CIPSafety safety profiles oriented towards identification of communication errors and recommendations of protective mechanisms which are applied in communication protocols. In the practical part the results of performed cryptanalytic attacks on the wireless communication protocol based on the IEEE 802.11 standard are mentioned.

KEYWORDS: industrial Ethernet, ProfiSafe, CIP Safety, Wi-Fi, Safety Integrity Level, cryptanalytic attacks

1. Introduction
In many cases the industrial communication subsystems are components of a system which participated in the safety critical process control. An undetected corruption of data transmission can cause considerable damages in the equipment, environment or human health and this is the reason why systems have to be designed so that guarantee the required Safety Integrity Level (SIL). For this reason the safety-related wired or wireless industrial equipment must have implemented a number of safety mechanisms located into special safety or security profiles [1].

Nowadays the number of industrial Ethernet type (wired or wireless) applications is increasing. At present many types of industrial Ethernet can be used in standard real-time applications. Several of them are additionally SIL3 safety profile certificated for the use in control of safety critical processes. Based on general principles, which are valid for safety related industrial communications defined in the standard IEC 61784-3 [2], the following safety profiles for CPF (Communication Profile Families) were certificated:
- CPF 1: Safety Foundation Fieldbus
- CPF 2: CIP Safety
- CPF 3: ProfiSafe
- CPF 6: Interbus Safety

After approval of the new standard ISA 100.11a [3] valid for wireless systems used in industrial automation the barrier to the use safety-related wireless machine-to-machine communications was broken. Wireless industrial Ethernet based on Wi-Fi, Bluetooth and ZigBee wireless technologies begins to be used in safety process control applications. An example of safety-related wireless communication with the master node is illustrated in Figure 1.

2. Solutions of safety industrial Ethernet
The unsuitability of standard IEEE 802.3 use in industrial applications in real time results from using a stochastic access method CSMA/CD (Carrier Sense Multiple Access/Collision Detection). This disadvantage may be
eliminated applying several principles and modifications to standard IEEE 802.3, which at the present leads to developing several variants of industrial Ethernet (see Table 1).

Nowadays on the technological level of control the industrial Ethernet replaces very popular fieldbus industrial networks and becomes the standard for large scale in the field of industrial control systems.

The advantages of using industrial Ethernet in distributed control system (DCS) are the following:

- Uniform structure of network on all levels of DCS.
- Compatibility with network of higher level of control in the DCS based on TCP/IP.
- Simplified configuration.
- Remote configuration.
- The possibility to use the existing network elements.
- The possibilities to use the existing information technology for remote access and www services in process automation.
- The possibilities to connect and address a large number of equipment.

According to the standard IEC 61784-4 [4] the safety solutions for open safety industrial Ethernet can be summarized in the following points:

- CP - ECI: External network interconnection to a control network.
- CP - IRA: Interactive remote access to a control network.
- CP - ICC: Inter control centres access to a shared control network.

These solutions can be generally implemented with the use of:

Safety solution of VPN (Virtual Private Networks) based on tunnelling communications protocols:

- L2TP (Layer 2 Tunnel Protocol).
- GRE (Generic Routing Encapsulation).
- PPTP (Point to Point Tunnelling Protocol).

Safety solution of Wi-Fi networks based on:

- SSID (Service Set Identification).
- MAC (Media Access Control).
- WEP (Wired Equivalent Privacy).
- WPA (Wi-Fi Protected Access).
- WPA2 (Wi-Fi Protected Access 2).

2.1. Solution of safety measures in safety industrial network Ethernet/IP

Safety industrial Ethernet/IP (Industrial Process) is based on the communication protocol CIP (Common Industrial Protocol) which supports many vendors and companies from the area of industrial automation. The vendors are concentrated within international organisation ODVA (Open DeviceNet’s Vendor Association). At present the protocol CIP contains the protocols from standard (SIL 0) industrial networks as DeviceNet, ControlNet, Ethernet/IP and communication profiles which expand the standard services of protocol. These profiles are the following:

- CIP Safety – used in the area of safety related communications (the idea is illustrated in Fig. 2).
- CIP Sync – used in the area of equipment synchronisation.
- CIP Motion – used in the area of distrusted control of motion.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC/PAS 62030</td>
<td>MODBUS - RTPS</td>
</tr>
<tr>
<td>IEC/PAS 62405</td>
<td>Vnet/IP</td>
</tr>
<tr>
<td>IEC/PAS 62406</td>
<td>TCNet</td>
</tr>
<tr>
<td>IEC/PAS 62407</td>
<td>EtherCAT</td>
</tr>
<tr>
<td>IEC/PAS 62408</td>
<td>Ethernet Powerlink</td>
</tr>
<tr>
<td>IEC/PAS 62409</td>
<td>EPA</td>
</tr>
<tr>
<td>IEC/PAS 62410</td>
<td>SERCOS III</td>
</tr>
<tr>
<td>IEC/PAS 62411</td>
<td>ProfinET</td>
</tr>
<tr>
<td>IEC/PAS 62412</td>
<td>P – NET on IP</td>
</tr>
<tr>
<td>IEC/PAS 62413</td>
<td>EtherNet/IP</td>
</tr>
</tbody>
</table>

Table 1. Variants of industrial Ethernet
The open idea of CIP Safety was certified by the organisation TÜV Rheinland Group with safety integrity level 3 (according to standard IEC 61508 [5]). In the first phase the CIP safety is implemented in safety DeviceNet network and the next extension is directed to networks ControlNet and Ethernet/IP. The CIP Safety assures simply the transmission of safety related and safety non related data across one medium and for the user allows to create a safety related connection between two (unicast) or several (multicast) applications [6].

Table 2 illustrates the safety measures, which can eliminate predicted communication errors during transmissions.

Table 2. The matrix of communication errors with relation to security measures implemented in CIP Safety

<table>
<thead>
<tr>
<th>Safety measures to detect communication errors</th>
<th>Types</th>
<th>Time stamp</th>
<th>ID of sender/receiver</th>
<th>Redundancy with cross checking</th>
<th>Diverse measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message repetition</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Message loss</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect sequence</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Message corruption</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Message delay</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coupling of SR data</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coupling of SR and SNR data</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Error of network element</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2. Solution of safety measures in safety industrial network ProfiNet

The new concept of safety related communication of industrial Ethernet – ProfiNet is called ProfiSafe. An additional safety profile ProfiSafe was SIL3 certificated and it is valid for industrial Ethernet types ProfiNet [7]: ProfiNet CBA (Component Based Automation) so-called ProfiNet V1, ProfiNet IO (Input/Output, Profinet V2) and ProfiNet IRT (Isochronous Real Time, ProfiNet V3). Versions V1, V2 and V3 of ProfiNet use different types of communication channels.

The ProfiSafe profile is compatible with Profibus and ProfiNet networks. The profile was designed on the basis of knowledge from the interlocking techniques used in the railway transport according to standard IEC 62280 [8]. The defined safety related measures eliminated the communication errors from untrusted transmission systems and guarantee the required SIL.

The ProfiSafe profile can be used in the following operation mode:

- Version V1 (V1.0 to V.1.2) – for safety related communication of Profibus DP/PA.
- Version V2 - for safety related communication of ProfiNET I/O and/or Profibus DP/PA.

Communication profile ProfiSafe is based on polling principle so called master – slave communication. Safety PDU (Protocol Data Unit) and its safety measures in the context of safety related (Fail safe - F) and combined with standard (S) communication is illustrated in Figure 3.

For elimination of communication errors (repetition, deleting, insertion, delaying, change of order, corruption, masquerade of messages and messages caused by network elements) in the ProfiSafe profile the following safety measures are recommended:

- Identification of source and destination addresses.
- Sequence number (virtual).
- Data integrity check.
- Time monitoring.
2.3. Solution of safety measures in safety industrial wireless Ethernet

When we compare wired fieldbus systems with wireless communication systems many similar risks occurring during the transmission are relevant also in wireless communication systems, but the wireless systems introduce also some new risks and the probability of failures is often higher than in the wired systems.

We can summarise basic threats to wireless communication in the following points:

- The transmission fades because the distance between the sender and receiver increases.
- The signal fades because of obstacles and environment conditions.
- Transmission signals are reflected from surfaces resulting in echoes and interference, or signal appears because of reflections from long distances.
- Two or more signals interfere with each other and cause proper signal for another receiver.
- Receiver is too sensitive.
- The nodes understand the network state or configuration differently at the same time.
- Security; intentional penetration to wireless network.
- Systematic failure, characteristics of wireless communication are not considered.
- Sleeping nodes in low power networks. Some nodes can be ordered to sleep to lower the power consumption i.e. longer battery life.

These communication threats can have the following consequences: the signal level is low, the bit error rate increases, the data is corrupted or lost, the signal can be delayed, and new messages may be inserted. There is no communication through a sleeping node until the node awakes and others.

In the communication between safety-related wireless machines all the risks or threats must be considered, safety requirements determined, adequate measures are applied to minimise the risks and the system is validated, the wireless communication can be a relevant possibility in safety-related machinery applications. Technical report [9] describes basic principles valid for safety and security profiles implemented in a wireless communication system.

The basic requirements for all cryptosystems are such as to make cryptographic mechanisms implemented in communication protocols resistant against known cryptanalytic attacks during all life time of system. To consider safety and effectiveness of cryptographic algorithm used the method to express the computational complexity of algorithms can be used, which is based on the principle of complexity theory. The operational demand of algorithm is determined by the asymptotic complexity, which is described by the behaviour of algorithm which will be changed according to input data of length \( n \). The operational demand is generally marked by notation \( O \) (called Landau’s notation or Bachmann - Landau’s notation) and is a function \( f \) of input data \( O(f(n)) \). The computational complexity determines generally three parameters: \( S \) (Space), \( T \) (Time) and \( D \) (Data).

Nowadays, the algorithms with exponential combinatorial complexity, which can be broken up in real time for small value of \( n \) input data only, are considered computational safety algorithms.

Basic specifications of communication Wi-Fi protocol are defined according to standard IEEE 802.11. Nowadays series IEEE 802.11a to IEEE 802.11n exist. Original cryptography standard IEEE 802.11 is based on the WEP (Wired Equivalent Privacy) protocol, which has implemented the stream Rivest Cipher RC4 (for data confidentiality) and checksum on the base of CRC (Cyclic Redundancy Check) CRC-32 (for data integrity). A standard length of the key is 40 bits, to which 24 bits of initialization vector (IV) are added. The key is represented by a hexadecimal number. An expanded key length in the WEP protocol is 104 bits with 24 bits of IV. Less safe kind of ciphering, which supported WEP protocol is now time replaced by cryptographic protocol WPA (Wi-Fi Protected Access), which uses stream cipher RC4 too, but the length of cipher key is 128 bits and the length of initial vector is 48 bits. Fundamental increase in safety is obtained using the TKIP (Temporary Key Integrity Protocol), which is the protocol for dynamic change of keys.

The use of this type of protocol is based on the server RADIUS, this solution is suitable for companies. For the private sector a simpler implementation exists via the PSK (Pre-Shared Key), in which the keys in all equipment are set forward. Protocol WPA MIC (Message Integrity Code) has been implemented (for integrity check) by so called MICHAEL. This method uses the check of the frames counter, what eliminates replaying attacks. Nowadays recommendation IEEE 802.11i defines advanced cryptography protocol WPA2, which replaced the protocols WEP and WPA.

In this protocol the stream cipher RC4 is replaced by cipher AES (Advanced Encryption Standard) [10], which is at the present the computational safety cryptographic standard, which replaced the symmetric cipher DES (Data Encryption Standard). Protocol WPA2 assures contents of authentication according to IEEE 802.1x and defines a new protocol CCMP (Counter Mode Cipher Block Chaining MIC Protocol).
3. Results of cryptanalytic attacks on wireless protocol

As it is well-known the WEP protocol is based on the RC4 encryption algorithm, with the secret key of 40 bits or 104 bits being combined with 24 bits of IV (Initialisation Vector). The encryption of message \( C \) is determined using the following formula:

\[
C = [M \| ICV(M) \oplus [RC4(K \| IV)]
\]  

(1)

where || is a concatenation operator, ICV is the integrity check value and \( \oplus \) is a XOR operator. Clearly, the initialisation vector is the key to WEP security, so to maintain a decent level of security and minimise disclosure the IV should be incremented for each packet so that subsequent packets are encrypted with the different keys. Unfortunately for WEP security, the IV is transmitted in plain text and the 802.11 standard does not mandate IV incrementing, leaving this security measure as the option for particular wireless terminal (access point or wireless card) implementations.

Security weaknesses of WEP can be summarised as follows:

• The weaknesses of RC4 algorithm due to key construction.
• The use of static key (maximum of 4 keys), changes only IV.
• IVs are too short (24 bits) and IV reuse is allowed (no protection against message replay, cycle only \( 2^{24} \)).
• The use of the same algorithm for encryption and authentication.
• No proper integrity check (CRC-32 is used for error detection and it is not cryptographically secure due to its linearity).
• ICV encryption with data.
• No built-in method of updating the keys.

These weaknesses are used in active and the passive attacks against the WEP protocol. The main attacks are as follows: brute - force attack (distributed and dictionary attacks), FMS attack, KoreK, Klein’s attack, attack PRGA, Man – in – the – middle attack and others (in detail see in [11]).

The attacks can be realised via different SW tools as AirCrack, Airbase, AirSnort, Chopchop, Sorwep, WepAttack, WEPcrack, WepLab and others, which are generally supported by Linux. The paper describes in detail the FMS attack.

The FMS attack (the name according to authors Scott Fluhrer, Itsik Mantin, Adi Shamir) is based on three basic principles:

- Some IVs form the cipher RC4 in the manner in which the information about the key in input bytes can be revealed.
- The weak invariant allows the use of the output bits to choose the most probable bits of the key.
- We can always discover the first output bits of the key, because they include the headline of SNAP (SubNetwork Access Protocol).

On the basis of capturing the couple (weak IV, the first byte of RC4 stream) it is possible to determine the secret key.

The Aircrack-ng application was used in the paper to implement the FMS attacks. The Aircrack is a WEP and WPA-PSK cracker, which is based on the passwords attack after summarisation of the sufficient number of packets. The Aircrack application contains three main utilities, used in the three attack phases required to recover the key:

- airodump: wireless sniffing tool used to discover WEP-enabled networks,
- aireplay: injection tool to increase traffic,
- aircrack: WEP key cracker making use of collected unique IVs.

The testing was carried out in the monitoring mode of attacker wireless card. The attack can be specified as a passive attack, because it cannot observe the authorised network operation side. The attack was realised in the following steps:

- The use of tool airodump-ng from the package of programme aircrack-ng:
  root@bt:~# airodump-ng -c 11 mon0
- Determination of file for writing of captured data:
  root@bt:~# airodump-ng -c 11 -w subor mon0
- A scan of wireless network via application airodump-ng – result (see Figure 5).

For testing purposes the network has been realised, which is illustrated in Figure 4.
The name of tested network was iWLAN. The testing was realised for two examples:
- The use of 64-bits WEP assurance with 40-bits secret key.
- The use of 128-bits WEP assurance with 104-bits secret key.

The breaking of WEP password is possible after capturing of sufficient number of frames with different IV only. In the realisation of FMS attack about hundred frames with weak IV was captured. For successful breaking of 64-bits WEP password (password: wi1fi) it was necessary to capture 20,011 frames.

The practice of breaking 128-bits WEP password was similar. At first the number of captured frames was 20,000 and the experiment was unsuccessful. The experiment was repeated and a successful breaking of the WEP password was realised with 78,131 frames.

4. Conclusion

Nowadays the number of safety communication profiles valid for safety industrial Ethernet is increasing. The trend is to use one safety profile for all types of industrial networks implemented within the technological level of distributed control systems.

In safety-related wireless communication it is necessary to choose the safety mechanisms according to standards relevant for the open transmission systems. In security critical applications to reduce the masquerading of messages the cryptographic mechanisms are recommended to be used. Cryptographic mechanisms provide different levels of safety in compliance with the type of cryptographic algorithm and length of its key. Under the results of realisation of one of best known cryptanalytic attacks on a standard wireless communication we can observe that this system without implementation of additional security layer does not fulfil the requirements for safety-related communication. In this case the value of SIL 0 is necessary to be increased to SIL 1 – 4 (by implementation of security communication profile).

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Statistical analysis of electromagnetic interference between AC traction current and track circuits

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ABSTRACT
The statistical analysis of traction current harmonics in rail circuits has been provided with the aim to develop statistical evaluation methods of electromagnetic compatibility between the AC traction current and rail circuits.

KEYWORDS: electromagnetic compatibility, AC traction current, track circuits

1. Introduction
The ensuring of electromagnetic compatibility of AC traction current with railway signaling systems is an important scientific and practical problem. The interest in it recently increased in connection with the occurrence of new types of rolling stock with asynchronous traction engines and microelectronic traffic control systems [1,2]. The evaluation of electromagnetic interference between the AC traction current and rail circuits (RC) is a complex and time consuming procedure due to a bundle of random factors that influence a form and value of the traction current in the rail lines, including the number of locomotives in a feeding zone, their operation mode, traction voltage fluctuation, variations of rail line-ground admittance etc. So the electromagnetic interference parameters also as parameters of rail circuit receivers (detectors) have a stochastic character. Papers [3,4] focused on the importance of taking into account of a casual character of electromagnetic interferences and immunity level of their receptors for correct evaluation of electromagnetic compatibility (EMC) of microelectronic systems. But in most publications on electromagnetic compatibility of traction current with railway signaling systems the stochastic character of systems parameters was not taken into account.

The purpose of this work is to develop statistical methods applicable to the evaluation of electromagnetic compatibility between the AC power traction current and rail circuits.

2. Statistical analysis
The methods and some results of locomotives traction current measurements were described in the author’s previous publications [5-9]. Since the traction current is a stochastic and in generally non-stationary process, it is essential to stipulate a statistical analysis methods used in the present work.

The realization of stochastic process obtained in k measurements of traction current $i_{Tk}$ may be expressed as the sum of the determined process $i_{Tk}^{D}$ specified by a locomotive control system in accordance with the appointed movement mode (regime) and stochastic process $i_{Tk}^{S}$ caused by random external and internal factors [10]
Random component \( i_{Tk}^S \) has zero average value independent of time, and, as shown in our work, has normal (Gaussian) probability distribution, that may be easy explained on the basis of the central limit theorem of probability theory in view of plenty of independent random factors that influenced the process. The function of a sample average value (mean) of the process is equal to determined function \( i_{Tk}^D \)

\[
E[i_{Tk}(t)] = E[i_{Tk}^D(t) + i_{Tk}^S(t)] = i_{Tk}^D(t)
\]

Therefore for a stochastic process with the alteration time that is much longer then the period of rail circuit signal current the random component may be removed using a low-frequency filtration, polynomial approximations or evaluation of time average of fragments sampled from the process realization \[10\]. For our investigations the low-frequency filtration of the traction current was provided by a computer program.

To calculate an average in time value of the current, the traction current oscillograms were quantized on sample sets.

Some sample sets that were measured at similar locomotive operation modes were considered as ensemble of independent process realizations for the evaluation of signal average as an arithmetic mean of the observation functions.

Samples length was determined according to the inequality

\[
T_H < T_{Tk} < T_{Tk}^S
\]

where \( T_{Tk}^S \) is the oscillation time of stochastic function, \( T_H \) - the maximal period of traction current interferences that are able to cause a failure in rail circuits operation (for rail circuits with signal current frequency 25 Hz and a filter pass band 25±6 Hz, \( T_H =26.32 \text{ ms} \) and the sample length for statistical analysis was taken not less then \( 10^2 T_H \)).

The sample period digitization was determined according to the inequality

\[
Df_d = \sqrt{2} f_C < \sqrt{2} f_{HM}
\]

where \( f_C \) is a Nyquist frequency.

The verification of stationary of the chosen samples was carried out by the first and second statistical moments. The verification of the hypothesis about similarity of dispersions in different samples of stochastic function was carried out by Kokrench criterion \[10\], and the verification of the hypothesis about a normal distribution electromagnetic interference value was carried out by \( \chi^2 \) - Pirson’s criterion.

Since most of the traction current measurements were
carried out in the locomotive during its movement, it is necessary to prove the application of these results to the analysis of electromagnetic processes in track circuits. The time and frequency domain plots of traction current measured in a locomotive and in rail lines at a distance from locomotive of 1 and 2 km are shown in Fig. 1 and 2. The amplitude of the traction current, as well as amplitudes of its harmonics were decreased with increasing distance to the locomotive. The harmonics attenuation rate during traction current propagation from locomotive along rail lines increased with frequency of harmonics that is evident when taking into account reactive components of the rail line impedance. Appreciable harmonics in a spectrum of the traction current in rail lines, which were additional in comparison with the current measured in locomotive circuits have not been observed. Therefore the rail lines parameters were practically linear at values of traction current that were set during measurements.

Mutual and auto correlation (covariation) functions of the traction current measured in a locomotive circuit \(i_L(t)\) and in rail lines \(i_R(t)\) were determined by the expressions [10]

\[
K_{LR}(\tau) = \frac{1}{T} \int_{0}^{T} \left[ i_L(t) - m_L(t) \right] \left[ i_R(t+\tau) - m_R(t+\tau) \right] dt
\]

\[
K_{LL}(\tau) = \frac{1}{T} \int_{0}^{T} \left[ i_L(t) - m_L(t) \right]^2 dt
\]

where \(m_L(t)\) and \(m_R(t)\) are the average values of stochastic functions.

For discrete samples

\[
i_L(n) = i_L(t_n) = i_L(n \cdot \Delta t)
\]

\[
i_R(n) = i_R(t_n) = i_R(n \cdot \Delta t)
\]

obtained on a realization interval, the covariation functions were calculated by the expressions [10]

\[
K_{LR}(m) = \frac{1}{n-|m|} \sum_{n=1}^{N-|m|} i_L(n) i_R^*(n+m), \ m \geq 0
\]

\[
K_{LL}(m), \ m < 0
\]

\[
K_{LR}(m) = \frac{1}{n-|m|} \sum_{n=1}^{N-|m|} i_L(n) i_R^*(n+m), \ m \geq 0
\]

\[
K_{LL}(m), \ m < 0
\]

The analysis carried out has shown high enough level of correlation between the current in a locomotive power circuit and in rail lines.

3. EMC in rail circuits

The statistical analysis of electromagnetic compatibility of rail circuits and traction current was provided for all frequencies of signal current used in the railways, but in this work only some results for the voice-frequency rail circuits with signal current 420 Hz are presented.

The measurements of turn-on voltage \(U_C\) and turn-off voltage \(U_B\) of rail circuits’ receivers were provided on ten different receivers of the same type with variation of an electric power supply voltage (in allowable limits) at different external conditions (temperature, humidity, etc.). As a result, 98 independent values of both turn-on voltage and turn-off voltage have been obtained. A statistical hypothesis about normal voltage distribution was checked up \(\chi^2\) – Pirson’s criterion at a 0.05 significance level. Values of a sample mean values and standard deviations of a turn-on and turn-off voltages were obtained: \(m_{UC} = 0.349 V, m_{UB} = 0.244 V, \sigma_{UC} = 0.0197 V, \sigma_{UB} = 0.0137 V\). Histograms of measured voltages \(U_C, U_B\) and the probability density function calculated using the obtained statistical moments are presented in Fig. 3.

Fig. 3 also presents the probability density distribution function of traction current harmonic voltage with frequency 420 Hz at the input of rail circuit receivers that was obtained from a statistical analysis of the traction current. For stationary locomotive movement modes the traction harmonic voltage was enough strictly described with normal probability distribution function.

For transient modes the interference voltage distribution had a more complex character and could be described for truncated normal or exponential function as the first approximation.

The results in Fig. 3 show that there is a finite probability that the value of 420 Hz harmonic interference at the input of rail circuit receivers may become greater than the turn-on voltage and even turn-off voltage of rail circuit.

![Fig. 3. The probability density distribution function of voltage of a harmonic on the input of RC receiver (a) and histograms of turn-off (2) and turn-on (3) voltages of RC receivers](Source: [own work])
receiver, when some of the most adverse factors would co-incide in time during the train movement.

Failure in rail circuits may take place when the voltage at the input of rail circuit receivers in normal mode operation decreases lower than the input turn-on voltage of receivers or when the voltage at the input of rail circuit receivers in shunt or control mode operation increased higher than the input turn-off voltage of receivers.

Probabilities of these events are equal

\[ P[U_{RN} < U_C] = \int_{0}^{U_C} f(U_{RN}) dU_{RN}, \quad (11) \]

\[ P[U_{RS} > U_B] = \int_{U_B}^{\infty} f(U_{RS}) dU_{RS}, \quad (12) \]

The probability that the input receiver voltage falls within interval \( (U_1, U_1 + dU) \) is equal to

\[ P[U_C \in (U_1, U_1 + dU)] = f(U_1) dU, \quad (13) \]

\[ P[U_I \in (U_1, U_1 + dU)] = f(U_1) dU. \quad (1) \]

Since these events are independent in pairs, probabilities of rail circuit’s failure in normal \( (P_{FN}) \) and shunt \( (P_{FS}) \) modes are equal to the product of these events probabilities

\[ P_{FN} = P[U_C \in (U_1, U_1 + dU_C)] \cap \]

\[ \cap \{U_{RN} < U_C\} = \int_{0}^{U_C} \left[ \int_{U_1}^{U_1 + dU_C} f(U_{RN}) dU_{RN} \right] dU_C, \quad (14) \]

\[ P_{FS} = P[U_I \in (U_1, U_1 + dU_I)] \cap \]

\[ \cap \{U_{RS} < U_I\} = \int_{0}^{U_I} \left[ \int_{U_1}^{U_1 + dU_I} f(U_{RS}) dU_{RS} \right] dU_I. \quad (15) \]

From the obtained equations it is possible to determine the probability of rail circuits failure when concrete statistical parameters of the input receiver voltage for normal, shunt and control rail circuit’s operation modes were preliminary measured.

### 4. Conclusion

The statistical analysis of traction current harmonics in rail circuits has been provided with the aim to develop statistical methods of electromagnetic compatibility evaluation between the AC power traction current and rail circuits. Time and frequency domain analysis of traction current in rail circuits has shown high enough level of correlation between the current in a locomotive power circuit and in rail lines. On the basis of the variance analysis of input voltages of rail circuit receivers mathematical equations were obtained that allowed to determine the probability of rail circuits failure when concrete statistical parameters of the input receiver voltage for normal, shunt and control rail circuit’s operation modes were preliminary measured.

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Possibilities and duties of ITS for large events

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ABSTRACT
In 2006, the FIFA World Soccer Championships was hosted by Germany. On that occasion new approaches on co-operative traffic management, new duties for ITS and new safety and transport strategies were developed and tested in and between the twelve hosting cities. Its success depended mainly on an actual and reliable information and guidance strategy as well as on a perfect operation of innovative ITS systems, on the way to the stadium and - maybe even more important - on the way back home. So traffic management with ITS played an important role in a suitable organization and operation of it. And the results would be good hints for other cities, regions or countries who will host similar events in the future.

KEYWORDS: ITS, traffic management

1. Introduction

The traffic management in the Hannover Region played and plays an important role during events as the worlds largest exhibition CeBIT, the EXPO 2000 and the 2006 FIFA Football World Cup. Instead of large and extremely expensive infrastructure measures for these special occasions, a variety of management systems and a multi-modal management center guarantees an excellent mobility for all users. Here, the strategic approach of a tidal flow system for exhibitions and the operational system during FIFA World Cup 2006 are in the foreground.

The Hannover Region with its one million inhabitants is an important intersection of European traffic routes – an also an important place for large events as the worlds largest exhibition CeBIT, the EXPO 2000 or the FIFA Football World Cup. The development as a meeting point for different types of events is supported by the good situation in the network of high quality traffic routes. Important European freeways with more that 100.000 vehicle/day and high speed rail routes run through Hannover in all directions forming an important road junction. Moreover, Hannover is located at an essential and vital inland waterway

1.1. Traffic Management for exhibitions

The Hannover Region also provides a high quality metro system and other very efficient transport networks. All together the traffic system is able to handle not only the whole commuter traffic, but also up to 300.000 more people arriving or departing as guests. But to handle this extra traffic which occurs only in certain weeks or months of the year, an extensive addition to the road infrastructure seemed not suitable. So an extensive traffic management system with the main goal of handling tidal traffic streams was developed and installed. The essential components of the extensive and unique traffic management system for vehicular traffic in the Hannover region are:

- conventional dynamic road network management systems as an alternative route control,
new dynamic road network management systems using LED technique and programmable displays (dynamic signposts with integrated congestion information) which are also able to indicate and give information about incidents and alternative routes,
• the complete equipment of the freeways in the Hannover area with control systems,
• the construction of an intersection management system at all heavily used intersections between freeways and fair expressway,
• temporary use of breakdown lanes during high volume time,
• an unique tidal flow system of more than 15 km length at the fair expressway with a semiautomatic control
• facilities of a dynamic parking guidance system for up to 45,000 slots and
• the implementation of a multimodal traffic management center for Niedersachsen in Hannover, where all these systems as well as the public transport management are controlled.

One of the innovative cornerstones is the tidal flow system on the fair expressway, where every morning and evening the incoming and outgoing traffic can use “double capacity” using also the opposite lanes. In a semi-automatic system with over 1,000 dynamic parts, hydraulic beacons, automatic barriers and video support a 16 km long area can be switched within 20 minutes – and with only 6 responsible persons acting in the center and on the site.

The fair expressway is the connection between the surrounding freeway system and the largest fair ground of the world. For many years the fair expressway has been used as a temporary one-way-street both for the arrival and for the departure at large events. These measures always required a large logistic and personnel effort, for example 350 policemen were used for this. When the planning for the 153 days lasting EXPO 2000 begun, it was clear that an innovative management had to be created to solve the problems.

2. Functional description

The main item of the system is the semi-automatic control of the fair expressway as a tidal flow system with numerous variable message signs and lane control signals. The system allows to assign at least four lanes – in sections with temporary use of the breakdown lane even six lanes – to the terminating or originating traffic depending on the traffic volume.

The protection of the motorists driving against the oncoming traffic and to design safe road conditions even in the weaving and sorting areas are a substantial issue of this control, that had to be tested in several experiments. Particularly innovative components are used to secure the connection area at the expressway intersection with the main freeway and the main sorting area.

Other individual components are variable message signs, lane control signals and newly designed marker posts that can be lowered pneumatically. Illuminated road studs at the main intersections and weaving areas are used as a variable stripe. In particular at the road junctions a wide range of components are necessary to create a high level of road safety as selected combinations of variable message
signs, horizontal swing barriers as well as corresponding signal controls.

The link located just north of the fair ground is equipped with facilities for a temporary use of the breakdown lane. The opening of the breakdown lane is indicated by variable message signs. While the breakdown lane is in use as a through lane dynamic traffic signs and even dynamic (illuminated) stoplines indicate this temporarily change of traffic control to the merging traffic.

At the intersections with the freeways an intersection management system helps to assign the lanes at the access ramps and the through lanes to either the ongoing traffic or to the merging traffic in dependency of the respective traffic volume.

The secondary road network close to the parking lots of the fair ground is equipped with variable message signs and lane control signals which allow another, smaller tidal flow system. A dynamic parking guidance system provides the distribution and guidance of the terminating traffic to free parking lots.

Components of the traffic management system:
- 104 signs on bridges with variable message signs or lane control signals
- 154 variable message signs
- 170 lane control signals
- 80 fibre optic displays for variable traffic signals e.g. speed limits
- 40 horizontal swing barriers
- 450 illuminated road studs
- 167 pneumatically lowered and raised marker posts
- 18 videocams at the fair expressway – 250 in city and region

When the operators in the traffic management center make up their decision to start the one way traffic the main program with detailed control sequences works automatically for about 20 min. With a control of almost 1,000 devices it switches the traffic management system to a safe state, prevents motorists from driving into the opposing traffic at the junctions, sets the signposting to the new operating state and indicates an appropriate speed limit. There are five control programs for different traffic situations. Additional broadcast information guides the motorists to the system and the opposing traffic to alternative roads.

Compared with the usual operation state a capacity increase of almost 100% can be obtained by using the tidal flow system at high traffic volumes. The incidents unavoidable at large events are reduces considerably. An additional safety profit results from speed limits indicated by dynamic displays depending on traffic conditions.

The success of the fair expressway traffic management system has helped to minimize investment on construction work for the road infrastructure just for temporary big events like fairs or sport events. This has proved to be especially successful for the world exhibition EXPO 2000 in Hannover when almost 20 million visitors were transported successfully within five months. By concentrating the traffic at the fair expressway the traffic volume on the municipal main roads and cross-town links could stay in a compatible quiet and mobile way.

The high flexibility makes it possible to use the available infrastructure including the traffic management center and its experience as well for the operation and control of the upcoming large events.

### 2.2. Traffic management for Large events

Tested since 1998 in its first elements, the traffic management system was ready for use for the EXPO 2000. But since then, it also demonstrated its capabilities at other events like rock concerts near the fairground. Then, in 2006, the FIFA World Soccer Championships was hosted by Germany. On that occasion new approaches on co-operative traffic management, new duties for ITS and new safety and transport strategies were developed and tested in and between the twelve hosting cities.

One important part of the strategy is to separate different "fans" to assure a large scale of security. This can be guaranteed in Hannover by guiding all the individual traffic to the exhibition parking spaces at the outskirts of the city and using only railroad systems for the connection to the stadium. This approach can minimize congestion, maximize the flexibility of the whole system, separate the fans of the different teams and leads to a 100% public transport arrival. But its success also depends mainly on an actual and reliable information and guidance strategy as well as on a perfect operation of innovative ITS systems, on the way to the stadium and - maybe even more important - on the way back home.

The 12 chosen World Cup cities were used in managing the traffic of a “Bundesliga” game every second weekend. But there are a lot of differences, as

- In the most cases it was not a Saturday or Sunday afternoon when the game was started, it sometimes was right during the peak hours of traffic. The beginning was at 3, 6 and 9 p.m. And above all a lot of people arrived much earlier in the morning or at noon.
- A lot of people were not used with the infrastructure in the destination city and even not known with the German language.
- The amount of media, sponsored and honorary guests was enormous (for the final game only two third of the entrance tickets were no “special tickets” in any case)
• A lot of visitors travelled with their teams over the whole period so there was additional traffic in other regions that could not be calculated before.
• Some minor groups of football fans were also of importance to the security group of the organisation. Certain matched were be sort of a special obstacle for the whole organisation team.
• In every city there were large outdoor screens for the people who were not lucky enough to get a ticket. So additional traffic problems occured that should not collide with the “normal” football traffic.

The traffic management organisation team Hannover started its work over three years ahead of the event, but an important step was to see what infrastructure could be used also after the World Cup and how special problems only occurring then could solved with a reasonable approach and above all with a minimized amount of money. The main approaches were already tested during the “Confederation Cup” in June 2005, when Hannover hosted three games.

For the World Cup, Hannover (as some other cities) renewed and enlarged their stadium. Changes in the rapid transit systems, new stations and enlarged parking facilities are other important measures for the infrastructure. But above all there are some operational approaches that are also a future hint for other events of this size and structure:
• The traffic management on the main highways reaching for all the 12 cities or connecting them is organized in a co-operation between the federal ministry and the road authorities of the different states and cities. Technically, large dynamic road signs are able to offer an alternative road in case of incidents, aditional radio announcements and dynamic TMC notations will be able to actually guide the visitors – and the normal traffic on the routes – on the optimal relations. For Hannover this leaded to a highly flexible system that enlarges the “tidal flow system” on the fair highway to a multi-entry multi-exit system for the whole region.
• The parking spaces of the City of Hannover were solely used for the citizens, for the parking facilities for the visitors were shifted to large exhibition grounds with a good public transport connection to the stadium. In Hannover the CeBIT fairground was used for all “normal” visitors, and from there they had a free ride with two different light rail lines (who separated the “fans”) directly to the stadium. Only press, VIP and buses reached the inner city with the stadium area.
• The guidance of the teams, the officials, the media and other special guests was separated from the normal visitor guidance. This made it necessary to work with a lot of dynamic road signs as well as public transport information systems, both flexible to incident measures and some even mobile for different purposes.
• The high number of visitors from other countries or at least other states in Germany made it necessary to enable the information systems to a higher flexibility. The main problem here was not the route to the stadium (and the traffic that approaches in the hours before the game) but the people leaving the stadium for their car or their public transport station. Here transport and security had to enable everyone to board the right right rapid transit for their parking facilities or even to go home without problems with “critical” groups of the other team.
• Above all the measures were fixed in a wide spread management strategy, a common management plan had been created, signed and was already fulfilled in a test during the “confederation cup” by all involved authorities in the transport and security sector, and a suitable operational group with all responsibilities and rights was installed similarly to the EXPO management years ago.
• At last a network of transport responsibilities in each city was informed instantly about things happened the evening before in the cities which hade games then. So the information exchange was not only good in the preparation, but also during the event.

The World Football Championship 2006 in Germany was one of the largest events in the first decade of our century. Traffic management with ITS played an important role in a suitable organization and operation of it. And the results would be good hints for other cites, regions or countries who will host similar events in the future.
Implementation Problems of Automatic Emergency Information System - eCall

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ABSTRACT
The concept of eCall automatically informing system of traffic accidents is one of the key-points of the European initiative eSafety and aims to create a Pan-European system of quick notification of traffic accidents. The system will use the telephone 112 or E112. The accident data will be transferred to emergency points. The estimation of costs and profits of the eCall system within the E-MERGE project and research SeiSS6 shows a possibility of avoiding even 2500 deaths a year and diminishing the results of accidents by about 15% on European scale. This paper presents rules of the eCall system operation and introduces some problems associated with the system implementation. The paper includes the eCall infrastructure, legal problems and the data transmission from a vehicle to a PSAP centre. The following technical issues are being discussed as well: accidents detection, ICT communication and data transmission in the voice channel.

KEYWORDS: eCall, 112, traffic accidents, telematics, ITS

1. Introduction
The concept of eCall automatically informing system of is one of the key-points of the European initiative eSafety and it aims to create a Pan-European system of quick notification about traffic accidents. The eCall refers also to the „Intelligent car” initiative that is aimed at creation of safe and ecological transport solutions. Automatic informing about traffic accidents is a service that will be available in every EU country and every new car produced in the EU. This will be the only Pan-European service that will not require any additional agreements or special equipment. In case of a serious crash, special detectors mounted in vehicles will automatically start emergency procedure in the on-board eCall unit.

This system will establish a connection based on E112 number. The rescue message consists of an MSD (Minimum Set of Data) transmission and a voice connection between the vehicle and a PSAP centre. The European Commission analysed many data transmission specifications that were proposed by private companies and chose the in-band voice channel transmission as the only satisfactory solution. PSAP operators will be also notified if the call was triggered manually or automatically. In the case of automatically triggered call and no voice response from the people inside the vehicle it is crucial to send emergency services as soon as possible. According to the results of the analysis conducted within the E-MERGE project financed by the European Commission, the eCall system will decrease the time of response by 50% in rural and 40% in urban areas. A rapid
treatment of injured people in consequence will decrease the number of deaths and mitigate the severity of injuries. The first hour after the accident is crucial to life and health of crash victims.

2. Principle of operation

The eCall system enables to inform rescue workers about accident's exact whereabouts by manual and automatic emergency calls. A manual call is activated by the driver/passenger with a special button next to the driver/passenger and an automatic call is made in specified conditions after detection of a crash. The eCall device will connect via the GSM network with the emergency service so it can transmit electronic data and initiate a voice connection. Notification is received by the emergency centre – a regional public service answering point that operates within the emergency telephone number 112.

The on-board eCall device will transmit a Minimum Set of Data (MSD) with the accident information and will try to initiate a voice connection between an emergency centre and the vehicle (Fig. 1). People in the vehicle during the talk with a trained e-Call operator can provide additional important information about the collision. The minimum set of data means the accident information which contains the time, exact location, vehicle data (VIN), eCall status (information about the notification type – automatic/manual) and the information about the GSM operator. The content of MSD notification is as follows:

There is a possibility of commercialization of the message-receiving phase. The eCall will be using the existing mobile network of the European emergency number - 112. When it comes to E112 number, there is a possibility of eCall device’s authorization.

Commercial solutions within automatic emergency calls are offered by: PSA (Peugeot Société Anonyme), T-Mobile Traffic, Ford, GM Onstar, Volvo OnCall, MAIF (Maryland Automobile Insurance Fund) but in the last 15 years their share in the market is less than 0.4%. This kind of service is offered only in high-end automobiles.

3. Accident detection and positioning

The eCall system enables to inform rescue workers about accident’s exact whereabouts by manual and automatic emergency calls. A manual call is activated by the driver/passenger with a special button next to the driver/passenger and an automatic call is made in specified conditions after detection of a crash. The eCall device will connect via the GSM network with the emergency service so it can transmit electronic data and initiate a voice connection. Notification is received by the emergency centre – a regional public service answering point that operates within the emergency telephone number 112.

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Table 1. MSD Structure

<table>
<thead>
<tr>
<th>Byte no.</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1       | Control            | Bit 7: 1 = Automatic activation  
|         |                    | Bit 6: 1 = Manual activation  
|         |                    | Bit 5: 1 = Test Call  
|         |                    | Bit 4: 1 = No Confidence in position  
|         |                    | Bit 3: Entity type could be added  
|         |                    | Bit 2: Entity type could be added  
|         |                    | Bit 1: Entity type could be added  
|         |                    | Bit 0: Entity type could be added  |
| 2       | Vehicle identification | VIN number according ISO 3779 |
| 3       | Time stamp         | Timestamp of incident event |
| 4       | Location           | GNSS Position Latitude (WGS84) and Direction of Travel (Based on last 3 positions) |
| 5       | Service Provider   | Service Provider IP Address |
| 6       | Optional Data      | Further data on e.g. crash information encoded in the XML Format |

Fig. 1. Scheme of the eCall system
Source: [own work]
4. Standardisation of the eCall system

The European Commission took actions on improving eCall regulations. The EC approached the ETSI (European Telecommunications Standards Institute) and CEN (Comité Européen de Normalisation) to develop open standards for the eCall system functionality. Most important issues were stated in the communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: eCall: time for deployment. These issues are:

- CEN approval of the structure of eCall Minimum Set of Data,
- 3GPP approval of the eCall discriminator ('eCall flag'), included in Release 8 of the technical specifications with which the mobile telecommunications systems must comply. This discriminator will differentiate between 112 calls from mobile terminals and eCalls, and also between manual and automatically triggered eCalls. This will permit Member States to design the eCall response infrastructure in the way that best fits their emergency response infrastructure (i.e. centralised/decentralised, the same PSAP that receives the 112 calls, or a different PSAP with a filtering function, a public organisation or a private one recognised by the public authority). Member States must inform mobile network operators operating in the country of the most appropriate PSAP to route eCalls.
- ETSI-MSG and 3GPP approval of the core technical specifications defining the protocols for sending the MSD from the vehicle to the PSAP operator. The solution agreed is that the data will be transmitted via an in-band modem along with the voice call. It is an open standard and there will be no licence fees for using the in-band modem for the eCall service.
- CEN approval of the core operating requirements for the Pan-European eCall service, defining the general functional and operational principles.

Work group CEN TC 278 WG 15 is responsible for preparing complex requirements for Pan-European eCall system. Researchers agreed on system standards and in autumn 2008 they started final phase of negotiations. We can expect that the final version of operational requirements will be accepted as “technical conditions”. Work group CEN TC 278 WG 15 is also working on private service providers’ cooperation with PSAP centres. Scheme of this cooperation is the following: in the case of emergency call a private eCall service provider will initiate connection with the vehicle, receive and decode the MSD message. Next, a notification will be passed to the PSAP. Private service providers can run additional services such as: vehicle supervision or car monitoring and fleet management. Compatibility of eCall devices with the PSAP centres requires the system assumptions for all European countries. Among many prepared standards, there are two key types: the data transmission standard and minimum set of data (MSD) sent from the eCall device installed in the vehicle to the PSAP centre. At the beginning of 2009 the European Committee for Standardization CEN (Comité Européen de Normalisation) has finished the work on MSD. However, methods and data transmission protocols are not defined in the document approved in February 2009 - CEN/TS 15722. Furthermore, CEN/TS 15722 standard requires legalization on the territory of European Union. Beside MSD it is necessary to prepare the data transmission protocol. The ETSI (European Telecommunications Standards Institute) and 3GPP representatives (3rd Generation Partnership Project - common mobile network standardization project) have already started working on the protocol. Producers provided data transmission devices, which were further examined. The in-band modem created by the Qualcomm company proved to be the best

<table>
<thead>
<tr>
<th>AIS index</th>
<th>Injury</th>
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<tbody>
<tr>
<td>0</td>
<td>Without injuries</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>Serious</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
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<tr>
<td>5</td>
<td>Critical</td>
</tr>
<tr>
<td>6</td>
<td>Unsurvivable</td>
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Table 2. Accident description with an AIS index

Fig. 2. Serious injury probability (MAIS 3+)
Source: [own work]
possible solution for a reliable transmission of MSD. The use of this modem fulfils all expectations in the field of MSD transmission and it does not require any modifications of the existing infrastructure and emergency number centre. During the tests with an unmodified PSAP centre, the operator had a voice connection with the vehicle in 2 seconds after the activation of eCall service. Moreover, this modem can be adjusted to two-way communication and MSD transmission giving better than expected connection speed 1.37 second – for standard conditions and 2.1 seconds for poor transmission conditions.

5. Conclusion

eCall devices will be mounted in all new-registered vehicles. In the case of a serious crash the vehicle detectors will automatically trigger the on-board eCall system that will start an E112 connection. It was assumed that the data will be transmitted in the voice channel (in-band transmission) according to the system functionality that requires simultaneous transmission of voice and accident’s data. The emergency message (MSD) will include the most important information about the vehicle and its location. MSD data will be decoded and displayed on a PSAP operator’s monitor. The location and direction of movement identification will be based on GPS data.

According to rapid growth of traffic in the EU countries and limited possibilities of building new road infrastructure, it is necessary to take actions that are aimed at improving the traffic flow and road safety. The implementation of the eCall system may save many human lives but it has to be preceded by preparation of standards and procedures that would be common for all EU countries. The implementation phase includes field tests on the territory of each EU country. However the true challenge will be the achieving of European interoperability between all devices produced by different manufacturers and with different PSAP centres.

In order to decrease the transportation’s impact on the environment and to reduce the costs resulting from transportation, the implementation of the Intelligent Vehicle Systems (part of the eSafety initiative) has begun. One of the three aims of the so called “intelligent car” initiative is the liquidation of obstacles associated with implementation of modern technologies on the automotive market. It requires cooperation of member states on the international forum and cooperation with the partners operating in the field of road safety. The European Commission developed the eSafety platform, which is an initiative connecting many concerned parties from both public and private sector. The eSafety forum, which was developed in 2003, associates currently over 150 associations and public administrative agencies. Formulated reports are an incentive for a development of a public policy and industrial initiatives. On a constantly increasing intensity of traffic and limited possibilities of development of the road infrastructure, it is necessary to undertake actions leading to increase in traffic’s smoothness and to passive and active solutions associated with the safety of traffic. The implementation of the eCall system can save many lives. However, it must be followed by the formulation of standards and procedures that will be launched in all of the European countries. Tests verifying the correctness of system’s performance in particular countries are foreseen as one of the stages leading to the system implementation. However, a real challenge is achieving a compatibility of devices produced by various producers with head offices all over the Europe. In Poland, it is necessary to undertake actions associated with developing concepts of structure and system’s performance, including cooperation with private entities providing services in the field of eCall system. In this field the Motor Transport Institute cooperates with other research and research and development entities, and private entities, including one of major Polish operators of telecommunication services. A test stand for an on-board study of eCall devices is being prepared. This will enable conducting further research in this field.

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AI and IQ- the Comparison and the Measuring Methods

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ABSTRACT
The hereby article is to present the notions of two concepts: human and artificial intelligence. The paper first offer the short presentation of their most common definitions. Both terms are widely known, however, not often are they viewed from the same perspective. Thus, the most intriguing part is to treat both issues in the similar, if not the same, way, using close assessment tools. Furthermore, the ways, methods and the approaches towards the assessment tools are provided. Finally, the comparison between those two concepts is shown, together with the idea of ITS as an example of AI.

KEYWORDS: AI, intelligence, IQ

1. Introduction

Since the times when humans stopped assessing and estimating their status and position from comparing the strength of their muscles only, various methods and names upon which the success in the life of an individual were evoked. As there is no one path and one position within a society, there appeared a need to create, first within the spoken, casual environment, a method, as objective as possible, to describe the reasons some people progressed faster and further than others in different goals, paths and careers. What was rooted within informal ways of assessing one social predator by another, transformed into a scientific label and acquired a name: the intelligence.

The intelligence was an answer why some, starting from the bottom, reached the peak of what a society offered. Lack of it served as a useful insult and as an explanation why some, despite monstrous efforts, are unable to learn from their own mistakes.

However, once created, the label was to develop as well; thus various scientific discussions, followed by reasoned arguments, concerning the definitions, what the intelligence actually is, and how we may measure it. There are numerous answers to those two aspects of the issue of intelligence; however, the scientific approach seemed to have become even more complex, when humanity development reached the era of technology. There appeared one more perspective: as there exist various machines, employed to perform the same work and actions as intelligent humans, can we assume the machines are as intelligent as their creators? The issue of an artificial intelligence itself seems disturbing for some; others tend to react overenthusiastically, aiming to prove whether a machine can outsmart a human. There again appeared a need to define what an artificial intelligence is and how we can measure it. Therefore, there were created not only the test to measure IQ, but also those which were to deal with AI.

2. IQ

IQ, a commonly used abbreviation of the words “intelligence quotient” seems to substitute the full word “intelligence” at least due to two reasons. First of all, vast majority of languages, English included, follow the rule of language economization, meaning that if something may be written or spoken in shorten than already existing version, it will, even if the meaning shifts a bit. Moreover, the abbreviation “IQ;” because, it seems, of the second part of the
name, refers also to the already tested and checked level of the intelligence, thus sounding more reliably than the intelligence itself. Having referred to the definitions of the issue of intelligence itself, within the rest of the article such abbreviation will be used as a kind of a synonym of the full name of that feature of character.

As mentioned before, there have been created many definitions to describe what the intelligence is. Together with the definition itself, there goes the approach towards the intelligence. According to Nęcka, “for the majority of psychologists, the intelligence is and perhaps will long be an individual value, which distinguishes a person from other people (…). The intelligence is also understood as a generalized feature, which means a feature that is revealed in various situations and intellectual tasks. We shall not call the swiftness in performing “in one’s mind” arithmetic equations the intelligence, if such actions are not accompanied with other, cognitive abilities.”[2].

According to the definition described above, one may decide that the intelligence is the ability to learn from one’s mistakes fast enough to profit from the constantly changing conditions of the environment, community or group one is within; it would also mean the ability to perform different tasks properly, despite the changing conditions of such performance.

Nevertheless, it is important to mention that the intelligence may have more than one meaning. Gardnem [5] presented seven different types of intelligence, which are follows:

• Linguistic,
• Logical- mathematic,
• Special,
• Musical,
• Bodily- kinesthetic,
• Interpersonal,
• Intrapersonal.

The profound division of various occurrences of the intelligence is widely known. However, for the sake of the discussion, within the rest of the article the notion of intelligence will be treated as one feature, without further divisions. The major value of the intelligence, it seems, apart from its use, lays within the ability to measure it; and although there do exist the claims concerning every of the known method of measuring the IQ, stating that none of the tests are reliable, as they test other features apart from the intelligence itself, nonetheless the ability to provide our environment with our worth not only with our deeds, but also with certain label, given from some authority that have assessed our abilities, presents us with certain advantage on the both private and professional ground. That is why, perhaps, despite some claims mentioned above, the IQ tests may enjoy ever-lasting popularity.

2.1. Wechsler Test

Strelau claims that “IQ tests and intelligence abilities tests may be described as standardized and normalized tools measuring intellectual ability basing on the effectiveness of performing mental tasks” [5]. Thus, there will be shortly described some most popular of them.

One of the most widely known tests are so called Wechsler tests [5]. The WAIS – R (PL) scale consists of eleven tests: six within the main scale, where the tested answers and five within nonverbal scale, where the respondent writes or fills the test in. the tasks, included into WAIS are as follows [5]:

• Information,
• Gaps in the pictures,
• Repeating the numbers,
• Putting pictures in order,
• Dictionary,
• Building blocks,
• Arithmetic,
• Jigsaws,
• Understanding,
• Digit symbols,
• Similarities.

It is claimed that the variant results from those eleven tests may be explained with three features: verbal understanding, perception organization and distractors resistance [5].

2.2. Raven Test

One of the most commonly used group tests is the Raven test. It is to assess liquid intelligence [5], meaning the level of general intelligence, understood as the value of the g factor. It standard version consists of five scales: A, B, C, D, E; in each of them there are twelve sentences (sixty together); the respondent is to find the relation between the formula and the lacking element. Together with the Raven test the lexicon is used to estimate the verbal abilities: there are nine subtests, five of which closed ones, which refer to so called passive speech, and four open ones which serve to create one’s own statements [5].

2.3. APIS Test and Omnibus Test

The APIS test, according to its authors, is: the intelligence test “intended for group assessment (…) the tasks are created to evaluate the abstract- logical abilities, as well as the verbal, optical- spatial and social abilities” [1]. The test itself was updated in 2005. The tests within it assess as follows:

• “behavior” test- the cognitive aspect of social abilities,
• “squares” test- visual- spatial abilities,
• “synonyms” test- verbal abilities, knowledge of words,
The last test to enumerate is the Omnibus test. It serves to assess the crystallized intelligence, understood as the declarative and procedural knowledge [1]. The test consists of five groups of tasks [1]:
- Filling in the verbal analogies,
- Filling in the series of numbers,
- Assessing if the conclusions are true or false,
- Finding antonyms,
- Finding synonyms for phraseological phrases.

The Omnibus test was normalized on students and applicants to Foreign Office and Civil Service Departments and therefore it is claimed to be prepared for people having above-average intellectual abilities [1].

3. AI

The notion of artificial intelligence, in most cases known from different science-fiction movies, is still a relatively new term. Philosophy Encyclopedia provides the reader with its detailed definition:

“The artificial intelligence is a relatively new branch of science, which deals with programming and examining the behavior of computers which are used both to solve some problems, intellectual, engineering and operational tasks, and as a psychological tool to model the mental abilities. The author of the notion is Alan Turing, who in his paper Computing Machinery and Intelligence replaced the question if the machines can think with the question if we could call intelligent such device, which behaves, writing questions and answers, in the same way as humans, meaning it is in this context undistinguishable from a human. The aim of the majority of the works concerning AI is to build such devices or programs, which perform certain actions, so that they would pass the test, no matter if it would be chess or proving mathematic theorems. Some people use AI techniques to build such machines which perform certain actions better than humans, or to perform such tasks, which humans could not do, meaning some intellectual tasks, as storing huge amount of data, using the knowledge from the certain branch of science, or some physical tasks, performed by robots” [3]. As it would be mentioned below, such definition apply as well to ITS, which would serve as an example of a device to undergo IQ tests tasks.

Alan Turing, to check his theory, build the device which is to check whether a machine may be undistinguishable from a human in a given aspect. The device is called “Turing machine”, as presented in Figure 1 [6].

The way how the machine works, is well described, among others, in Stanford University materials. According to it, a Turing machine is a type of state machine. “At any time the machine is in any one of a finite number of states. Instructions for a Turing machine consist of specified conditions under which the machine will transition between one state and another.

A Turing machine has an infinite one-dimensional tape divided into cells. Traditionally, it is thought of the tape as being horizontal with the cells arranged in a left-right orientation. According to the first version, the tape has one end, at the left say, and stretches infinitely far to the right. Each cell is able to contain one symbol, either ‘0’ or ‘1’.

Within the same description, the machine has a read-write head, which at any time scanning a single cell on the tape. This read-write head can move left and right along the tape to scan successive cells. The action of a Turing machine is determined completely by the current state of the machine, the symbol in the cell currently being scanned by the head and a table of transition rules, which serve as the “program” for the machine.

Each transition rule is a 4-tuple:
< State0, Symbol, Statenext, Action >
which can be read as saying “if the machine is in state State0 and the current cell contains Symbol then move into state Statenext taking Action”. The actions available to a Turing machine are either to write a symbol on the tape in the current cell (which we will denote with the symbol in question), or to move the head one cell to the left or right, which we will denote by the symbols « and » respectively.

If the machine reaches a situation in which there is not exactly one transition rule specified, i.e., none or more than one, then the machine halts” [4].
3. Is IQ equal to AI?

As described above, there is not a machine able to deceive the assessors and prove to behave as a human. Therefore, we may draw the conclusion than intuition and intuitive thinking, and thus the ability to learn from the changing circumstances in which the task is performed is the main difference between the concept of IQ and the AI. Nonetheless, is that mean people tend to overuse the term “intelligent” towards machines?

If we decide to examine the most popular test assessing human intelligence, we may notice that although there exist certain areas where it would be impossible for a device to prove its usefulness, there are still those in the test that ma bye equally well, if not better, performed by artificial “mind”.

The areas tested in Wechsler test are within the reach of ITS in the similar extend as for a human. Both need to be filled with information to be able to use it, one may even risk the claim that the teachers in that situation may be the same, for example, yet another device with vast data stored in it. The example of such digital teacher may be some servers, storing Internet sites; the only difference in getting the knowledge would be in acquiring it: by reading or by transferring, but isn’t reading a way of transfer as well? In case of ITS, one may claim they work on the exactly the same basis: the system also needs to be “filled with” the data in order to work properly; it also need to have working principles developed; and as the software development may be compared to storing the data within the “tester”, the whole process, both in case of human and in case of a device, is similar.

In case of the APIS test, one may note that the ability “to behave oneself” also relies on the current state of knowledge about the socially accepted behaviors. It may turn out, as it is often stated in the companies of multinational staff, that a person described as a perfectly polite and apt to follow all social rules in one environment may be considered rude when meeting members of a different community where other rules of behavior apply. One may recall a situation of shaking hands: in majority of western countries such gesture is regarded as a perfectly polite start of a meeting, whereas, as it is constantly reminded on various trainings, we should not expect a Japanese to provide us with such performance, which obviously does not mean Japanese are impolite; however, they may regard a westerner, who does not bow at the beginning of each meeting, as equally lacking knowledge of socially desirable behaviors.

The Omnibus test may seem a bit more difficult to sustain such comparison at the first glance. However, basing on the assumptions presented above, one should compare the lever of the language knowledge of an average student with the data stored within any digital dictionary- would it not the latter be more able to provide the assessor with numerous synonyms, antonyms or analogies present in a given culture? Once again, the knowledge “stored” within a mind and that within a disc may be quite similar.

3. Conclusion

The theory could be stated that all the eleven elements of Wechsler test may be obtained on similar level by both a machine and a human, or by a device, in the given example ITS; it could be similarly estimated in case of other tests, as both a human and a system need first to be learnt and then one may expect a positive outcome of the task that they need to complete. The greatest difference in learning, in case of human, and acquiring, in case of machine, lays, one may conclude, in the role of a third party involved in the process. Whereas the first stage in both cases would be almost identical, meaning that both would need some tools as well as a teacher who/which would present how to use them, the second and further stages differ more and more. It means a human, having completed the first stage of learning, may proceed to the level where the role of a teacher becomes less and less important, and they may start to depend on the tools mostly, if not entirely; of course, the level of intelligence would matter in the ability to cope with the tools without the manual provided by a teacher,
as well as with the ability to define the tools they need and to find them.

Therefore, one may draw the conclusion that the difference between those two issues, AI and IQ, is the question of the distance that may be covered on the learning path. Could that mean the machine may be to cover similar way of self-developing as a human? Taking into consideration the newest surveys concerning the artificial neuron networks, perhaps one may just note that it is far too early to decide yet. AI may not equal IQ, but the way of estimating the results of both labels may be surprisingly similar. Coming back to the notion of ITS being tested on its “intelligence” it may be stated that even if the system may not be able to pass the Turing test yet, it is nevertheless intelligent, if we decide to use that word in the meaning of comparing the way it performs its “duties” and follow the tasks with the way the same work be performed be a human. It needs to be emphasized that the difference between calling a human intelligent and using the same name to describe the system is, in fact, time—the time people need to make devices follow the path we have covered.

Bibliography

Application of the HDR imaging in vehicles’ video tracking systems

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ABSTRACT

Video systems are used in Intelligent Transportation Systems for vehicles’ tracking. Cameras typically used in these systems are characterized by relatively low dynamic range which is only a fragment of the dynamic range of the human eye. In order to adapt to the lighting conditions the cameras feature dynamic changes of the gain and exposure. For vehicles there is a very wide range of the observed brightness of details because of the variety of vehicles’ colors and the presence of elements reflecting light in different ways, as well as changing lighting conditions. This means that even if the camera is able to capture the relevant dynamic range, there is a restriction of the distinguishability of details, which is essential in the process of detecting the location of vehicles. The use of HDR imaging techniques based on various exposures helps to increase the dynamic range and improves the accuracy of vehicles’ positions estimation.

KEYWORDS: vehicles’ tracking, High Dynamic Range images, Intelligent Transportation Systems

1. Introduction

Intelligent Transportation Systems (ITS) utilize various types of road sensors for the estimation of the traffic parameters [1]. The use of the video cameras is probably the most interesting approach, since they allow measuring some parameters, which are unavailable using some other technologies. The cameras are usually installed at a given height over a road, such that a relatively large area can be monitored. Typical places for such installations are buildings or dedicated pylons, especially outside urban areas.

One of the main advantages of the video cameras is the ability to measure many traffic parameters, even in different fragments of the road, using only a single camera. Nevertheless, some digital image processing and analysis or pattern recognition algorithms have to be applied for this purpose. Furthermore, due to the installation over the road, there are no problems related with possible surface damage during the installation, in contrast to some road built-in sensors (e.g. inductive loop, optical pressure sensors etc.) [1,2].

The use of the video cameras in the ITS has also some disadvantages, especially high sensitivity on the weather conditions. Using the near infra-red (IR) cameras the camera’s sensitivity can be increased (usually the IR filter is not used, so the camera has high sensitivity for the near IR but the visible light range is also handled). The cameras working for medium and far infra-red range (thermographic) have much greater scope but presently their prices are also very high. The full color video cameras working in the visible light range allow also the estimation of the vehicles’ colors and the increase of the separation between the vehicles on the obtained images. Probably, the dominating trend in the ITS applications will be related to the multi-spectral analysis, since each range can be characterized by its unique advantages.

A serious limitation of the video cameras is the dynamic range of the acquired intensity of light. The expected range is the same, or even wider, as the Human Visual System (HVS), but the image interpreted by a human brain is strongly processed. Presently available technologies, both
digital cameras and photographic film, are just a taste of the possibilities of people.

A typical image acquired by a digital camera is usually overexposed or underexposed (often both problems occur on the same image). This phenomenon is especially evident in the ITS applications where a fragment of the background may be dark and opaque, similarly as some of the vehicles, while some others may be highly reflective (metallic). The dynamic range of the camera working in the sunshine should be very high, but unfortunately this cannot be obtained even using modern cameras.

There are some cameras with nonlinear acquisition characteristics for the CCD [3-5] but at the moment such equipment is rather experimental than commonly available. A possible solution, also for existing infrastructure, can be the High Dynamic Range (HDR) image acquisition [6]. Such images can be acquired during the process of multiple acquisition of images for different exposures followed by their fusion into a single image with a wider dynamic range using digital image processing algorithms. This operation can be performed using a series of video frames acquiring using the same camera, using several cameras [7] or using the CCD with various sensitivity of its pixels.

2. HDR imaging for the ITS

The development of the HDR technology occurs in two directions. The first one is related to the processing of the HDR images and the second one is their conversion to the Low Dynamic Range (LDR) images (tonemapping), necessary for the display using the currently available monitors.

The most relevant aspect for the ITS applications is the image processing allowing e.g. better acquisition of the image for further processing e.g. recognition of the vehicle’s type.

In this paper the low cost solution based on the existing systems with controllable exposure time is analyzed. The varying exposure can be used for the cameras equipped with an electronic shutter. Such solution is effective, since it does not require any moving parts working continuously inside the camera.

The approach proposed in the paper is based on the various exposure time for each acquired frame, tracking of the vehicles for each of them and the fusion of the obtained images in order to obtain the HDR image. In the consequence, both tracking and the HDR imaging is obtained.

Commonly used algorithms of the fusion of complete images utilize the alignment methods for the matching of the consecutive frames, especially when they are obtained from the moving camera without a tripod. Assuming the static camera, such additional alignment is unnecessary. Nevertheless, the ITS applications require the use of a modified alignment algorithm. The camera and the scene (treated as the background) are static, but the fragments of the images representing the vehicles are located at various positions on the images acquired for the various exposure times.

The first step of the algorithm, which is applied independently for the image pairs, is the background estimation leading to the result image transformed such that it contains only the static elements. The simplest approach is the long-time averaging of frames [8]. The vehicles visible at various locations on the image are treated as noise. Since their colors and brightness are different, the average tends to the background image. Better results can be obtained for the algorithms detecting the differences of the images, allowing faster convergence and more adequate results.

Using the difference between the current frame and the estimated background with the same exposure time, the differential image can be obtained. Using the thresholding the membership of the pixel to the vehicle (above the threshold) or the background (below the threshold) can be specified. The area of the image containing the vehicle is usually called a blob due to its specific shape.

For a large number of vehicles the kinematics estimation algorithms should be applied in order to determine the track for each of them. For the simplification, a single vehicle observed from a side is assumed in the paper. For the identification of the method’s possibilities the synthetic analysis is performed, but for the real images obtained from the camera, some other observation angles can also be used.

The tracking of multiple vehicles is possible using the Multiple Hypothesis Testing (MHT) algorithm [9]. For the tracking of vehicles various kinematics estimators can be used e.g. Kalman filter [10,11], which allow the prediction of the current position based on the previous measurements, so the obtained result can be compared to the nearest blob location in the current measurement. The difference between the prediction and the location is then used for the filter’s update.
The tracking process can utilize all the measurements obtained using various exposure time. In the cases, when the blob is not detected using the thresholding the reason may be related to e.g. too short exposure time, only the result of prediction is used as the location estimation. Due to the synchronization of the measurements obtained for various exposure time with the respective exposure values, the tracking can be continued even without the presence of the blob in several frames.

In order to determine the HDR image of the vehicle, which can be useful e.g. for the classification purposes, the fusion of the images acquired for different exposure time is necessary.

For the proper alignment of the consecutive frames, the correlation of the images obtained for different exposure time should be calculated, what in not always an easy task. For all images a common range of luminance, present in two frames is necessary. For three different exposure times, the middle frame should contain the common range at its both range boundaries. The resulting image is then combined using the intermediate images.

There are many algorithms of image fusion used in the HDR imaging. One of the most convenient ones is the Mean Threshold Alignment (MTA) [12,13], because of its high processing speed and relatively good results. The idea of the method is based on the grayscale image processing so the first step is the conversion from the RGB image performed for all pixels as:

$$Y = 0.299 \cdot R + 0.587 \cdot G + 0.114 \cdot B \quad (1)$$
For each \( j \)-th image the median value \((MED_j)\) is then calculated used further for thresholding

\[
B_j(x, y) = \begin{cases} 
0 & : Y_j(x, y) \leq MED_j \\
1 & : Y_j(x, y) \geq MED_j
\end{cases}
\]  

(2)

where \( B_j(x, y) \) is the binary value of a specified pixel.

The pair of images with a common fragment of the dynamic range can be compared using the XOR operation:

\[
E_j = \sum_{x,y} B_j(x, y) \oplus B_{j+1}(x, y)
\]

(3)

and the matching process corresponds to the minimization by searching:

\[
\min \sum_{x,y} B_j(x, y) \oplus B_{j+1}(x + \Delta x, y + \Delta y)
\]

(4)

where \( \Delta x \) and \( \Delta y \) denote the relative translation of both binary images. For small images the translation by one pixel can be used in order to check all the combinations, but for larger ones some optimization methods can be useful.

The images obtained after matching should be further processed using the camera response curve, which should be determined for each exposure time.

For the cameras used in the ITS the luminance calibration can be performed for each exposure time, so the luminance transform process is simplified, in contrast to the unknown exposure time or unknown luminance curves (not always linear). Nevertheless, such curve can also be determined for a given camera using a calibration table.

After the transformation of the image series into a single HDR image, some further algorithms of image processing, analysis and recognition can be applied.

3. Conclusions and future work

The utilization of the HDR imaging for the video based vehicle tracking can be a promising direction of research related to the development of the machine vision algorithms for the ITS applications. Presented preliminary
results obtained for some synthetic images seem to be helpful for some other algorithms used on the Intelligent Transportation Systems, especially related to the statistical traffic analysis as well as e.g. register license plate's numbers recognition in various light conditions.

Nevertheless, matching the images obtained for the varying light conditions may be troublesome in some situations and some more sophisticated algorithms should be used. The application of them, also for some real images acquired from the video cameras, is planned as a part of our future work.

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Bibliography

Interaction of Real and Embedded Devices for Intelligent Control of City Electric Transport

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ABSTRACT
The interaction of real and virtual devices is an important point in the design and development of control system. The central part of an embedded control system is a controller and it needs input devices and output sensors for realization of the control. The proposed approach allows using a real controller with its specific programming tools and languages for intelligent software development and virtual measurement and sensor devices realized in a computer environment. Different wireless compounds are necessary for intelligent embedded devices for transport system control. For this reason a wireless communication network is needed to ensure the data transmission between the controller and supervisory control and data acquisition system. The purpose of this paper is to propose an approach for interaction of real, embedded and virtual devices in electric transport control systems. The main tasks are: to analyze objects and functional dependencies of an electric transportation control system, to develop a control algorithm with the interaction of real and virtual devices, to ensure a wireless connection for the data transfer from the controller to the supervisory control and data acquisition system, to define the method of transmitted data processing. Computer and practical experiments, with real and embedded devices, and the results analysis will be described the paper.

KEYWORDS: electric transport, embedded systems, intelligent control

1. Introduction
Real and virtual interaction devices are an important point of recently developed control system design, as it is often used in various types of computer programs and have created a meter, which increases levels of automation and modifying the system itself. Often there is a place for different wireless connections, which are used in transportation systems, dynamic systems are very important to direct wireless connections, where the transfer takes place. Therefore, a question arises related to the wireless data transmission such as sending the data to the controller, or reading the data from it.

1.1. Purpose and tasks
The purpose of the paper is to present the Interaction of Real and Embedded Devices for Intelligent Control of City Electric Transport.

The main tasks are to:
- Create a management system for electric vehicles;
- Choose the transfer of necessary parameters;
1.2. System description

After several urban electric transport developments of a control algorithm using programmable controllers, a need arose to expand the research possibilities of this direction by creating a possibility of visual data control and further online processing. It was therefore decided to use a program environment, enabling to differentiate between the data processing and graphical monitoring. A conclusion was drawn that the main compatible object in this system is the controller program, which will make the tram traffic visualization model, and that a server is required to transfer the data.

Real devices are:
- Electrical engine E
- Traffic light L₁
- Traffic light L₂

Virtual sensors are:
- Engine rotation speed w
- Traffic light L₁ coordinate X₁₁
- Traffic light L₂ coordinate X₁₂
- Traffic light L₁ lighting light g₁₁
- Traffic light L₂ lighting light g₁₂

To gain an insight into the nature of the data transferred a small survey of electric transportation management system and the tram traffic management program should be considered.

The control program action comprises:

- The controller enters the management program of the tram model (un-engine), simulating the movement on the tram route, the route comprises traffic lights and stop – L, P (Fig. 2.). An electric vehicle T shown in the figure consists of components such as an electric motor E and controller C.
- The management principle was highlighted in the traffic safety promotion, first in putting brake prohibitive light signals and points to the corresponding braking acceleration. Management program provided to speed the admission of the stops, or parking at the denying light signal.

After a successful management program launch there was a need for visual observation of this process in motion that would allow evaluating fuller the developed control algorithm and detecting possible improvement algorithm stages. It should be mentioned that the visual graphical analysis of the parameters was really fruitful.

As the next point we can see all the objects and components that will be involved in the control system, as well as the variables that characterize these objects.
- The main objects that will be used for our tram management model:
  - Tram (T);
  - Passenger stop No 1;
  - Passenger stop No 2;
  - Passenger stop No 3.

- Components which include the above-mentioned principal objects:
  - The tram:
    - Positioning sensor (P₁);
    - Rotational speed sensor (A₁);
    - Speed sensor (A₁d);
    - Completed road sensor (V₁d);
    - Braking distance sensor (B₁d);
    - Transmitter (R).

- Variables corresponding to the above attractions:
  - The tram:
    - Coordinate X₁;
    - Engine speed w;
    - Speed V;
    - Completed road S₁;
    - Stopping distance at the current speed S₁u.
  - A passenger stop:
    - Coordinate X₁.

1.3. Task solution

As the program, which will be used for data processing, the Matlab environment was chosen because it provides a great opportunity for data receiving and processing.

![Data flow chart](fig1.png)

**Fig. 1. Data flow chart**
Source: [own work]

![General structure of the system](fig2.png)

**Fig. 2. General structure of the system**
Source: [own work]
Then the PC Access program was selected for setting up a Data Transfer server.

The challenge program explained was created in a Matlab visualization model (Fig. 3.) Processing the next data received from the controller:
- $X_{L1}$ – The first set of traffic lights coordinate
- $C_{L1}$ – The first set of traffic lights (red, yellow or green)
- $X_{L2}$ – The second set of traffic lights coordinate
- $C_{L2}$ – The second set of traffic lights
- $X_P$ – passenger stop
- $X_T$ – tram coordinate

These are the most important system parameters, because they are characterized by direct tram running processes and the influences acting.

Similarly, there was an opportunity to read any parameters, which are stored in a controller, by entering the address of the PC Access program building a server (Fig. 4).

As the next step, we run the program controller, or propose a tram run along the route, have an opportunity to visually monitor it and, where necessary, to process the data received from the controller parameters.

It should be noted that inserting the Matlab program model, in addition to the OPC Write block, got a chance to enter the necessary parameters, or change the existing online mode, i.e. to run the model studied remotely using a wireless connection. The model with the maximum was created simply to allow monitoring the tram routes, traffic lights, the lights on and the tram itself.

One of topic developments planned is to completely withdraw from the wi-fi use for the data transfer, and use the GPS and GSM, which will be connected to the controllers who will control the motor and traffic lights.

A simplified block diagram for this case is shown in Fig. 5.

The block diagram used the following blocks:
- P – Satellite
- C – Controller
- E – Electric engine
- M – Measuring instruments
- L – Traffic lights
- GPS – GPS antenna
- GSM – GSM antenna

This addition will require the use of aerial control program development, but at the same time, the system capacity will increase the future, maximally close to the actual working conditions. The data visualization is also possible...
using devices directly connectable to the controller, such as various boards, which can output a variety of emergency messages, electric transportation coordinates, engine parameters, speed of electric transportation, other electric transport speeds and coordinates, etc.

1.4. Experiment

The real algorithm for the equipment checking was situated in a stand (Fig. 7.), comprising an industrial programmable controller for Simatic 224 xp (1), "ethernet" block (2), the power supply unit (3), fuse (4), router (5) providing the only wireless connections to computers, two traffic lights (6), DC motor (7).

During operation, the "Step-7" program was connected to the controller and the program loaded up. “Simulink” medium was prepared by the open model, which graphically depicted different parameters, both at the tram movements (Fig. 8.).

It was possible to depict graphically the data received, showing as they change in time. Figure 9 shows the speed on the tram route and stops depending on changes of time.

In this way, we can send the data to controllers in a real world of urban electric transport.

For a bench operation, the engine control was used in the controller output, which generates a voltage with variable pulse width. This was practically the only size that was controlled and registered in reality; in other calculations the values required were obtained directly from the removal of this parameter. In reality, parameters such as the path covered by the tram, speed, etc. will be received from various sources, but in our model the relevant parameters need to be calculated by the control program itself.

2. Conclusions

The developed control algorithm also provides tram stops and braking before the traffic lights with a specific set of acceleration.

With regard to the data transfer process it can be concluded that the data transfer was stable and accurate, as well as fast enough. This gave the opportunity to work in a sufficiently precise visualization model.

It was possible to develop algorithms that will involve a real device, such as GPS and GSM antenna for transmitting the data, which enabled to transfer the data at such distances, which are required for electric transportation routing time.

Overall, we can definitely say that in the future the built-in intelligent systems will be applied for further improvement to real objects in urban or interurban electric transport, increasing the safety, accuracy and efficiency.

Bibliography


Role of Fleet Controlling in Logistics

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ABSTRACT
The paper deals with the role of fleet controlling in logistics. Main benefits of its application for transport companies (dispatcher, fleet manager etc.), drivers, customers and logistics are described here. Other parts of the article solve the application of fleet controlling in the road transport of high-value cargo and in the field of intermodal transport.

KEYWORDS: Fleet Controlling, road cargo transport, valuables cargo transport, intermodal transport

1. Introduction

Fleet controlling (FC) belongs to the overall concept of “Fleet Management System” (FMS). The FMS is a total concept for ITS (Intelligent Transport System) applications in the field of vehicle-fleet management. The FC is now the last development stage of FMS. That is why terms FC and FMS are equivalent today.

1.1. The development of fleet management/controlling

In 1980-ies the search for stolen vehicles, using “tracking” method, begun in the United States of America. In 1995 the American Department of Defense allowed public using of Global Positioning System (GPS). This facilitated general cost-free use. Mainly after the year 2000, when the willful inaccuracy of position detection was removed, the boom of satellite navigation started.

The main presumptions of FMS realisation were the development of GPS technology, mobile communication GSM, data transfer technology GPRS and also systems of data reading from various sensors in vehicles.

Four development stages of FMS are distinguished: Tracking, Monitoring, Fleet Management and Fleet Controlling. “Tracking” enabled only simple vehicle tracking; “Monitoring” made possible data reading from the vehicle bus. The stage “Fleet Management” already enabled on-line communication between a dispatcher and driver and the current stage “Fleet Controlling” enables complete vehicle-fleet administration and management and fully uses the GPS technology. The total economic agenda of each vehicle is enabled too.

Two FC types exist. The first is called “internal FC” – when the fleet management is fully controlled by a company which owns the fleet. And the second type is “external FC” – when the fleet management is outsourced to another company.

Well-known companies, which offer FC technologies, include e.g.: Berg Insight, Frost and Sullivan, YMS Czech Republic. [1] [3] [4]

1.2. The application of fleet controlling

The FC can be applied to any vehicle-fleet. The main areas of FC use are fleets of:
- trucks,
- buses,
- taxi-cars,
- police-cars, ambulances, fire-trucks,
- army vehicles,
- company cars (authorities, offices),
- construction machines (crane trucks, excavators).

This article is focused on the FC of truck-fleet mainly.
1.3. Principles of fleet controlling

The FC is based on on-line (real time) communication between a driver and certain employee of the road hauler in the office (dispatcher, vehicle manager, etc.). The communication is based on principle of writing and sending messages. The communication is similar for example to “ICQ” communication program.

Other important principles of FC are: vehicle tracking/tracing (using GPS) and the transfer of information on driver’s work (driving, safety breaks, etc.), vehicle technical data (speed, consumption, etc.) and cargo data. [1] [4] [5]

2. Communication and control areas

There are three main areas of communication and control here. These are: the driver, vehicle and cargo.

2.1. Driver

At first, the FC provides information on driver’s work – driving times, rest times, times of loading/unloading, etc. The driver’s work in the European Union is (among others) regulated by Regulation 561/2006/EC. This regulation gives all time-limits of driver’s work. The FC-system cooperates with a digital tachograph in a vehicle, so the dispatcher has the current information on driver’s working mode.

The second function of FC is the transfer of data related to driver’s driving style. For example the data concerning: current/maximal speed, gear-changing accuracy, safety and support systems’ activation – e.g. ABS, ESP, and driver’s vigilance control system. [4] [5]

The third area of control is pursuing procedures of loading and unloading and on-line communication with the driver on traffic and transport matters.

2.2. Vehicle

Some areas of communication and control from the “vehicle area” are mentioned in part 2.1. Pieces of information which are transferred from the vehicle to the dispatcher or the fleet-manager include: actual engine revs, engaged gear, fuel status, instantaneous and average fuel consumption, engine temperature, vehicle load (per axle, total), tyre pressures, etc. [4]

It is of course necessary that the vehicles are equipped with systems, which allow certain data transmission. For example: to provide a dispatcher with the information concerning axle-loads, the vehicle has to be equipped with the ECAS system (Electronically Controlled Air Suspension). In a similar way the TPM system (Tyre Pressure Monitoring) is essential to the transfer of information on tyre-pressures.

2.3. Cargo

The FC allows observing the beginnings, processes and ends of cargo loading/unloading procedures.

If the vehicle is equipped with ECAS, the dispatcher has the information on real cargo weight. This can be used as a basis for transport invoicing. If a vehicle carries some perishable cargo (according to the ATP agreement) the temperature in the loading space can be observed.

After unloading at the consignee’s place the immediate invoicing can be done. The FC also supports the use of electronic documents – EDI (Electronic Data Interchange). [5]

3. Main requests related to truck-fleet controlling

The main request related to the FC used for truck-fleet is the satellite navigation with up-to-date maps including “truck attributes”. These attributes are mainly: bridge bearings, underpass (tunnel) heights, allowed vehicle widths, car parks/rest areas suitable for trucks, traffic prohibitions into certain areas. Another request (as mentioned hereinbefore) is the on-line communication between the driver and dispatcher (vehicle manager).

4. Benefits of fleet controlling application

The FC offers benefits for all parties concerned. The first party comprises transport companies and their “office employees” – top-managers, dispatchers and vehicle
Managers. The second party is formed of drivers. The third party consists of customers (cargo consignors and consignees) and the logistics itself. And the fourth party comprises the society. [2] [4] [5]

Main benefits for transport companies:
• actual positions and activities of vehicles;
• easy service planning;
• driver's work and vehicle operation optimization;
• labour productivity increase;
• sufficient usage of the fleet;
• monitoring of drivers' work (driving times, rest-times, drivers' "behaviour");
• evidence of taking holidays;
• lower operating costs (fuel, tyres, maintenance, repairs, etc.) – e.g. company Volvo declares 5-15 % decrease of fuel consumption of a vehicle fleet, if using its DynaFleet system;
• lower phone costs;
• easier wage planning;
• better ergonomics of the office work (less phone calls, quieter environment);
• quick reactions to customers' requests;
• immediate invoicing after the cargo delivery.

Main benefits for drivers:
• access to digital maps in sat-nav with truck attributes;
• up-to-date information on the traffic situation on certain route (congestions, detours);
• information on traffic prohibitions (e.g. low-emission zones in certain cities);
• the FC system complies with driving/resting rules (as mentioned herebybefore in 2.1);
• information on weather;
• information on driving bans in European states;
• less phone calls with dispatchers, less notes.

Main benefits for customers and logistics:
• increased effectiveness of cargo transport;
• real-time information on the consignment (cargo) position;
• information on the consignment status – e.g. "loaded", "on-route", "unloaded";
• for a perishable consignment (ATP agreement): on-line control of given temperature during loading/unloading, transport, warehousing;
• quick and safe transport.

Main benefits for the society:
• increase in the road transport safety;
• higher fluency of road traffic;
• lower environmental impact of the road transport (lower fuel consumption – lower emissions);
• social profitability in the field of sustainable transport and development.

5. Fleet controlling in the field of valuable cargo transport

Valuable cargos comprise mainly tobacco, cigarettes, alcohol, electronics, computers and pharmaceuticals. Besides requirements mentioned hereinbefore, there is a high demand for transport safety in the field of valuable cargo transport.

Semi-trailer combinations are mainly used for valuable cargo transport. Semi-trailers are specially constructed. They have a box loading space with strengthened walls and rear door. They are also equipped with motion and light sensors in the loading space.

The whole process of transport, loading operations and warehousing of valuable cargo in Europe is regulated by standards of TAPA-EMEA (Transport Asset Protection Association – Europe, Middle East and Africa). [2]

5.1. Loading operations

The rear door of a semi-trailer can be opened (e.g. at the place of loading or unloading) after multiple unlocking. At first, the driver has to make a phone-call to the dispatcher and ask him to perform remote unlocking of the door. This unlocking operation takes approximately two minutes. Then, the driver has to use his personal chip and enter his personal code on the keyboard. The keyboard is situated in a locked case on a semi-trailer. After entering the code, the driver has 50 seconds for opening the semi-trailer door. After this time the door is automatically locked and the whole procedure of unlocking has to be done again.

If a driver (or any other person) would have tried to open the door without unlocking by the dispatcher (or without using the chip or entering the code), the alarm would have been set off. The alarm means an immediate warning report on dispatcher's computer and in the "safety-centre" (see below). The driver has no access to loading and unloading procedures. This principle increases safety of these procedures.

5.2. Transport

The driver has a route previously defined by the dispatcher. The dispatcher sends the driver certain part of the route to driver's GPS navigation. The dispatcher does not send the whole route from a loading place to unloading place. He
sends only a certain route stage – e.g. from the loading place to a place where the driver will spend his rest time.

The satellite vehicle tracking is something obvious, of course. One of the most important things in the field of valuable cargo transport is that “safe truck-parks” are defined. These truck-parks comply with requests of TAPA. In extraordinary cases (when the dispatcher allows so) the driver can stop on a “not safe” truck-park. In this case the vehicle (semi-trailer combination) has to be secured using geo-fencing technology. However this service is very expensive.

Main reasons to alarm set off are:
- diversions from the defined route;
- decoupling of semi-trailer;
- the use of “safety button” in the driver’s cab;
- forced entry into a semi-trailer.

For example enterprise LOG-IN is equipping their drivers with a special mobile phone “Benefon”. There is a safety button on this mobile phone. The driver has two safety buttons available to use.

Drivers are trained how to act during a case of emergency, such as:
- assault on the vehicle (while driving, during rest-times);
- unexpected change of defined route e.g. by a reason of assault, detour or road check (weighing etc.).

In the case of assault on a vehicle, the driver presses the safety button in the truck-cab or on his mobile phone. Thanks to this, the dispatcher and the safety-centre (in the case of LOG-IN they outsource this duty to the company CSM) are immediately informed about this situation. The safety-centre guarantees the transport company that its employees (or policemen) will be at a vehicle in 15 minutes.

In the case of a road check, the driver has to inform the dispatcher about this situation, so that there will be no alarm. [2]

Main benefits of the FC in the field of valuable cargo transport are:
- separate position control of prime-mover and semi-trailer;
- on-line driver to dispatcher communication;
- GPS and GSM antennas are built both in the prime-mover and in semi-trailer;
- safety buttons in the driver’s cab and on the mobile phone;
- motion- and light-sensors in a semi-trailer;
- sensors on rear door of a semi-trailer;
- sensors of coupling on the fifth-wheel of a prime-mover.

### 6. Fleet controlling in intermodal transport

From the view of consignment’s position monitoring the intermodal transport (ITR) is significantly more complicated in comparison to a direct road transport. In the case of direct road transport it is sufficient to monitor certain truck.

In the ITR it is necessary to monitor the consignment (loaded in certain transport unit – e.g. ISO container, semi-trailer, swap-body) during:
- transport by road;
- transhipment and warehousing in ITR terminals;
- transport by other transport-modes – rail and water transport mainly. [3]

The position monitoring of certain transport unit has to be possible without repeated phone calls. For example the company ZOCA Container Security offers a tracing service for ISO containers during the whole transport process from a consignor to consignee. [6]

Significant requirements of the FC system applicable to ITR are: up-to-date information concerning consignment’s position and complex, reliable and correct information

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Fig. 2. Transhipment of a semi-trailer in an ITR-terminal
Source: [7]

Fig. 3. GPS device mounted on an ISO container
Source: [6]
from all parts of transport (road transport, transhipment, warehousing of transport unit, rail transport etc.). Also all actors participating in the ITR have to be willing to share all important data among each other – so that the system of FC in the field of ITR would be able to operate.

7. Conclusion

The main purpose of the FC system is to offer on-line (real time) information concerning a vehicle fleet. Main areas of information transfer are:
- driver's work and his driving style;
- vehicle's position;
- operating and technical data about a vehicle;
- cargo (consignment) data and position.

The FC is based on on-line communication between the driver and dispatcher, fleet manager, or administration employees.

The main goal of the FC is to secure effective, economical, ecological and safe operation of vehicle fleet. The FC enables cost-reduction in the field of vehicle fleet administration.

Bibliography

Usage of Infrared Camera in Active Safety Systems

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ABSTRACT
The intelligent systems supporting the driver start to play a decisive role in avoiding vehicle collisions in dynamically changing road conditions. Systems cover the following fields: prevention, passengers safety, support and information. In that case we are dealing with an integrated safety system, which is much broader then an individual car or personal skills of a driver. The implementation into a common usage of sophisticated safety systems is aimed at early warning, monitoring the situation on the road, mutual interaction and functionality of the systems in changing road conditions. The huge technological investments of car producers result in safety improvement and avoidance of majority of car collisions. The most recent safety active systems, which are broader described in the article, include the systems, which use IR cameras, such as: Driver Alert System - DAC (Driver Alert Control) and LDW (Lane Departure Warning) as well as City Safety System.

KEYWORDS: safety systems, car collisions, prevention

1. The intelligent systems supporting the driver

The intelligent systems supporting the driver start to play a decisive role in avoiding vehicle collisions in dynamically changing road conditions.

For a long time car producers in cooperation with systems suppliers have been working on the development of technologies which would protect against car collisions and as a result against consequences they may cause. One can observe a visible trend in ways of placing orders by car producers. Car producers are ordering whole systems for the new car models. For example, a brake system supplier secures for car producer the whole range of products – starting from electronic units ending on a brake fluid.

Similar situation is in safety systems. They consist of many functions of active and passive safety, called by suppliers CAPS – Combined Active & Passive Safety Systems. System suppliers have to guarantee system delivery in the following fields: prevention, passengers safety, support and information.

In that case we are dealing with an integrated safety system, which is much broader, then an individual car or personal skills of a driver. The implementation into a common usage of the sophisticated safety systems is aimed at early warning, monitoring the situation on the road, mutual interaction and functionality of the systems in changing road conditions.

These huge technological investments result in safety improvement and avoidance of majority of car collisions.

The most recent safety active systems include the systems, which use IR cameras, such as:
- Driver Alert System [DAC (Driver Alert Control), LDW (Lane Departure Warning)]
- City Safety

2. Driver Alert System.

The Driver Alert System warns the driver when the vehicle is being driven in an unsteady way or is about to leave its lane unintentionally, e.g. due to the driver...
being distracted or being tired. Clear side markings on the carriageway are required for the Driver Alert System to function. The Driver Alert System also warns a driver whose driving is deteriorating or who is unintentionally leaving the current lane.

The Driver Alert System consists of the following functions:

DAC (Driver Alert Control): informs and warns the driver that his/her attention, and accordingly driving style, has deteriorated due to fatigue, for example.

LDW (Lane Departure Warning): alerts the driver when the vehicle is about to unintentionally leave its lane.

The FSM (Forward Sensing Module) uses the information from the camera in the windscreen to continuously read the carriageway’s side markings. As the camera has similar limitations to the human eye the performance of the Driver Alert System is affected by external factors such as light conditions, road conditions, rain and snow and fog.

For the camera to have mist-free vision through the windscreen, there are electric coils in front of the camera’s field of vision controlled by the FSM.

2.1 DAC (Driver Alert Control)

The DAC warns the driver when his/her attention, and accordingly driving style, has deteriorated due to fatigue, for example.

The FSM uses the information from the camera to identify the carriageway’s side markings and then by these means to calculate the extent of the road. The FSM can assess whether the vehicle follows the lane consistently by continuously comparing the road’s assessed stretch with the information about the driver’s steering wheel movements. This means that if the driver is tired but is still driving well enough then the system does not detect anything. It may also mean that the system warns when the vehicle is affected by strong side winds.

If the driver’s driving style deteriorates then this is indicated on the information display in the driver information module (DIM). The driving style is indicated by a level marking of 1–5 bars, where 5 bars means a stable driving style and 1 bar means unstable driving style.
When the level marker drops below 1 bar, the driver is alerted by an audible signal. At the same time, a message is displayed on the information display in the DIM warning the driver to take a break.

The DAC is switched off and on in the menu system in the ICM. When the DAC is switched on the function is activated at 65 km/h and is then active at all speeds above 60 km/h. The driver can check whether or not the function is available (i.e. whether or not the camera can detect the side markings) by selecting Driver Alert’s trip computer page using the left-hand stalk switch. Current status is then shown on the information display in the driver information module (DIM).

2.2. LDW (Lane Departure Warning)

LDW warns the driver when the vehicle is about to leave its lane unintentionally.

The FSM uses the information from the camera to calculate the position of the vehicle in relation to the side markings. If the vehicle crosses the left or right-hand side markings unintentionally, the driver is alerted by an audible signal.

The switch for the LDW is located in the CCM. Using the ICM menu system, the driver can select whether the function should always be switched on from the start and the degree of sensitivity for the function.

When the LDW is switched on the function is activated at 65 km/h and is then active at all speeds above 60 km/h. The information display on the driver information module (DIM) shows whether the function is active and whether or not the function is available (depending on whether or not the camera can detect the side markings).

3. City Safety

The City Safety is a function for helping the driver to limit or avoid collisions at low speeds. In a situation where a collision is likely to happen, for example, when the vehicle in front brakes without the driver behind reacting, the vehicle will brake itself by applying the foot brake.

According to statistics, 75% of all reported collisions occur at speeds below 30 km/h. The figure may even be higher because the consequences of minor collisions may be limited and not always reported to insurance companies. With the City Safety these collisions can be limited or fully avoided.

The City Safety is active at speeds below 30 km/h and it can detect both stationary vehicles and those driving in the same direction as the City Safety system’s own vehicle. The driver can switch off the function during the current operating cycle via the menu in the trip computer. The system is designed to report to vehicles the size of a passenger car or larger.

A rangefinder is used in order to detect the vehicles in front. The rangefinder is part of the control unit, CVM (Closing Velocity Module), and is fitted in the upper part of the windscreen.

The CVM is standard on all XC60 and is used for:
- City Safety
- Prepares the vehicle’s SRS in the event of an imminent collision.

The driver is always responsible for ensuring that an adequate distance is maintained to the vehicle in front and that the speed is adapted to the current traffic situation.

If the vehicle is equipped with the CMS then these functions complement each other.
The CVM is located in the windscreen’s upper edge and, besides the CVM control module, also contains a rangefinder.

The rangefinder reads an area around 6 meters in front of the vehicle by means of a laser sensor. The laser sensor projects an infrared light invisible to the eye every 10th millisecond with a wavelength of 905 nm.

A laser diode produces the infrared light which is projected through a lens in three fields:
- Left
- Centre
- Right

Together the fields cover an angle of 27°. If any object is in front of the vehicle the light is reflected and recorded by three photodiodes. The CVM measures the time it takes for the light to travel from the sensor, reflected from the object in front, and back to the photodiodes. The time is used in conjunction with the vehicle’s speed to calculate the distance to the object in front, and also the speed difference between the vehicle and the object in front.

The laser diode produces an infrared light invisible to the eye which is projected through a lens in three fields. The laser diode is a further development of the LED. The light’s wavelength, 905 nm, is constant. Following the illumination of a laser diode it is gradually heated by the operating current.

If the operating current is not adjusted there is a risk that the laser diode will be overloaded. An operating current that is too high results in the laser diode failing.
A very dark surface may have only 5 % reflection. An object with a low degree of reflection means that the maximum measuring distance drops significantly. The best measurement objects are those with a special reflective tape that provides very high reflection values, such as a number plate.

Something that also affects measurements is the structure of the object's surface. If the beam is aimed at an object that has a structure that is not uniform, the beams are reflected in a variety of different directions. This also affects the measuring distance because the energy in the light that is reflected decreases when the reflected light is not aimed back to the transmitter.

The rangefinder reads an area around 6 meters in front of the vehicle by means of a laser sensor. The field covers an angle of 27°. As the IR camera has similar limitations to the human eye the performance of the system is affected by external factors such as light conditions, road conditions, rain and snow and fog.

As the speed of the laser diode’s light is known, the CVM module can calculate the distance to the object in front. The CVM module can also calculate the difference in speed between the vehicle and the vehicle in front. Based on this information, the CVM module can calculate the retardation (braking effect) required to reduce the speed of the vehicle so that a collision is reduced or avoided.

The rangefinder in the CVM module uses laser light within the wavelength for IR light, which means that this function would otherwise be filtered away by the IR windscreen unless the heat insulating film has been removed in the area in front of the rangefinder.

This means that the IR light transmission in front of the rangefinder on the IR windscreen will be slightly higher than for a standard windscreen which has a certain heat insulation in the laminated film.

The CVM module receives information about the type of windscreen fitted in the vehicle via the vehicle configuration file in the CEM (Central Electronic Module).

It is important that the same type of windscreen is fitted when replacing the windscreen, as the light transmission through the windscreen is known by the CVM module.

If this is changed, whether it be higher or lower, the performance of the system will deteriorate. If a scratch, crack or stone chip occurs on the windscreen in the field of vision in front of the CVM module which is greater than 0.5 x 3.0 mm, then the windscreen must be replaced.

The rangefinder emits the invisible laser light from ignition position II, regardless of whether or not the vehicle’s engine is running. Looking directly into the opening of the rangefinder (which emits invisible laser radiation) with magnifying optics such as a magnifying glass, lens or similar optical instruments at a distance of less
than 100 mm involves a risk of injury to the eyes. A dis-
smantled CVM module fulfils laser class 3B. Laser class 3B is not safe for the eyes and accordingly constitutes a risk of injury.

5. Conclusions for Practical Purposes of Diagnostic Systems with an IR Camera

The operation of the systems with IR camera may be disrupted by:
- ice or snow on the bonnet
- ice, snow or dirt on the windscreen
- heavy rain, snow/snow flurries or fog
- hanging load on the roof
- accessories such as auxiliary lamps, grille guard etc. in excess of the bonnet’s height
- decals adhered to the windscreen in the rangefinder’s field of vision
- the structure of the object’s surface
- scratch, crack or stone chip on the windscreen in the field of vision in front
- not illegible marking of horizontal lines of the road
- false data in the configuration file in the CEM module (for example the information on the type of windscreen)
- Faults in CAN bus communication protocol between system modules

For effective diagnostics of systems with an IR camera the unique data regarding the analyzed system are necessary. As it has been proved in the article the only step by step diagnosis may not lead to effective system improvement, it leads only to unwanted change of vehicle modules.

Bibliography:
Service quality management in multipath access solutions for transport telematics solution

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ABSTRACT
ITSs (Intelligent Transport systems) are associated with serious expectations and getting ITS applications in the real practice is understood as essential potential to significantly faster resolve many transport challenges. Research is concentrated on the promotion of ITS architecture in real ITS practice and using it for solving the different ITS optimization tasks. In this paper main afford is oriented to the communications key support of the ITS architecture.

KEYWORDS: Intelligent Transport System, Transport telematics, Multipath seamless communications access service, Bayes statistics, Laplace density function

1. Introduction
ITSs (Intelligent Transport systems) are associated with serious expectations and getting ITS applications in the real practice is understood as essential potential to significantly faster resolve many transport challenges. Research is concentrated on the promotion of ITS architecture in real ITS practice and using it for solving the different ITS optimization tasks. In this paper main afford is oriented to the communications key support of the ITS architecture.

2. Telematic requirements communications solution
ITSs (Intelligent The first step in addressing the ITS architecture requirements is the analysis and establishment of performance parameters in designed telematics applications, in co-operation with the end-users or with organizations like Railways Authority, Road and Motorways Directorates, Airport and Air-transport Authorities, Government etc.

The methodology for the definition and measurement of following individual system parameters is being developed in frame of the ITS architecture and it is described in [1] - [5].

Substantial part of the system parameters analysis is decomposition of system parameters into individual sub-systems of the telematics chain. This step represents analysis of requirements on individual functions and information linkage so that the whole telematic chain should comply with the above defined system parameters.

The completed decomposition of system parameters enables application of the follow-up analysis of telematic chains according to the various criteria (optimization of the information transfer between a mobile unit and processing centre, maximum use of the existing information
and telecommunication infrastructure, etc.). It is obvious that quantification of requirements on relevant telecommunication solutions within telematic chains plays one of key roles in this process.

Mobility of the communication solution represents one of the crucial system properties namely in context of specific demand on availability and security of the solution. Monitoring and management of the airport over-ground traffic was one of our key projects where our own approach to system solution was designed and tested. This application is characterized by strict regulation and successful tests of ITS system under heavy airport conditions can be understood as the representative telematic reference.

Data transmission capacity can act due to possible high density of moving objects and limited wireless capacities critical system requirements, which can be resolved either by application of broadcasting regime of data distribution or by selective individually reduced frequency of positional data distribution. Distance between objects or moving objects density in area represents simple but effective criteria for such individual data distribution management.

Following communications performance indicators quantify communications service quality (see e.g. [6] - [10]):
- Availability – (Service Activation Time, Mean Time to Restore (MTTR), Mean Time Between Failure (MTBF) and VC availability),
- Delay is an accumulative parameter and it is effected by either interfaces rates, frame size or load/congestion of all in line active nodes (switches),
- Packet/Frames Loss (as a tool which not direct mean network failure),
- Security.

Performance indicators applied for such communications applications must be transformable into telematic performance indicators structure and vice versa. Indicators transformability simplifies system synthesis. Additive impact of the communications performance indicators vector $\mathbf{tci}$ on the vector of telematics performance indicators $\mathbf{\Delta tmi}$ can be expressed as

$$\mathbf{\Delta tmi} = \mathbf{T} \cdot \mathbf{tci}$$

where: $\mathbf{T}$ represents transformation matrix. It is valid, however, only under condition that probability levels of all studied phenomena are on the same level and all performance indicators are expressed exclusively by parameters with the same physical dimension – typically in time or in time convertible variable (see e.g. [7]). Transformation matrix construction is dependent on the detailed communication solution and its integration into telematic system. Probability of each phenomena appearance in context of other processes is not deeply evaluated in the introductory period, when specific structure of transformation matrix is identified. In [7] - [10] are presented details of proposed iterative method. Method is designed as broadly as possible with clear aim to be applied in the widest possible range of telematic application. This method can be also successfully used for identification of decision processes criteria, i.e. tolerance range of each performance indicator. Such information represents necessary (but not sufficient) condition to let processes decide which access technology is in defined time period the best possible alternative.

3. Calm

Family of standards ISO TC204, WG16.1 “Communications Air-interface for Long and Medium range” (CALM) represents concept of identification of the best available wireless access solution in given time and area. Process of the alternative wireless access solution substitution is understood as the second generation of the handover principle known in its first generation namely from the cellular mobile systems. Each handover process is predestinated by set of performance indicators range identified for decision processes implemented in the control unit. CALM standards have implemented Policy-Based Management (PBM) approach. This concept has been traditionally and successfully applied in the IP based terrestrial networks. Such approach, however, has got remarkable limits for wireless networks discussed later in this paper.

Details of CALM architecture are described e.g. in [11] and [13]. Handover in CALM is implemented on the L2 of the TCP/IP model. Alternative approach based on standard IEEE 802.21 - see e.g. [14] - expects integration of the L2 switching into handover process, as well, even though with this system approach we identified remarkable advantages against the “CALM” alternative.

Authors solution is based on L3 routing and this approach we would like to categorized as “intelligent routing”. Such approach offers advantage of the exclusively SW based implementation and no special HW requirements on OBU (On Board Unit) installed in the vehicle.

4. Mutli-path access solution structure

Second generation handover action can be determined by evaluation of the performance indicators set like Bit Error Rate (BER), Packets Lost Ratio (PLR) or packet Round Trip Delay (RTD) as well as remarkable number of other e.g. “radio” parameters with different level of influence on the final decision. Decision to switch to the alternative path is so complex issue with high number of input
parameters. Number of inputs can be limited, if significant parameters are identified, and all other known parameters can be accepted as insignificant. Such afford to identify the key performance indicators has been basis for our specific studies of all available telecommunications technologies used in the transport telematics.

Adaptive communications control system has following architecture:

- 1-st layer – Cellular Layer (CL) - represents feed-back control processes of parameters like transmitted power, type of applied modulation etc. Goal of processes on this layer is to keep given set of managed parameters like e.g. Bit Error Rate (BER) or Round Trip Delay (RTD) within required limits.
- 2-nd layer – the first generation of handover (1HL) represents seamless switching process between cells of the same mobile network. Such approach is applied in mobile systems like GSM, UMTS, Mobile WiMax or Mobile WiFi (802.11r). 1HL layer typically shares resources with CL layer (delivered usually as one system) so that there is no risk of contra-productively simultaneously operated processes on both layers - of course only - if it is correctly designed and operated. These solutions are, however, mostly designed as “close” ones, i.e. nothing like APIs are available.
- 3-rd layer – the second generation of handover (2HL) is mostly dependent only on identification of the service performance indicators. It is for sure that the effective management on the 2HL layer can be much easier reached if 1HL and LC layers are opened for relevant information exchange with layer 2HL.

Critical issue can be identified in potential simultaneous processing on the different layers of the processes. Such activities can be contra-productive, and, all potential decisions and actions should be well synchronized.

5. DOTEK

Decision processes representing basis for adaptability of communications wireless services have not been deeply enough resolved issue in ISO CALM standards. CALM standards recommend on Policy-based Management (PBM) approach. This concept has been traditionally applied in the IP based networking and we can only state its remarkable success.

L3 routing based on “deterministic decisions” was applied in project of the communication module for transport telematics - DOTEK. “DOTEK approach” ensures the best wireless access solution selection from the set of available wireless services and it is based on system parameters benchmarking derived from the telematic application requirements recorded in form of required parameters range into the “decision” table.

The main objective of the DOTEK project was motivated by the CALM family of standards. However, principal difference if compared with “CALM approach” was implementation of the “intelligent” routing principles replacing L2 switching used in case of CALM solution. DOTEK project was focused mainly on the following areas:

- Analysis and selection of available wireless services applicable for different transport telematics services.
- Design of comprehensive management including decision algorithm for selection of optimal data transfer technology.
- Provisioning of the continuous monitoring and evaluation of given services quality necessary for the correct decision to select appropriate service.
- “Table based” processing of the decision in order to ensure proper operation of telematics applications.

An important part of communication module is to monitor current system parameters and communication technologies in order to assess their current situation and decide about their suitability for use according to the specific requirements of telematic applications. Telecommunication technologies are described by system parameters like:

- availability,
- delays (latency),
- packet/frames loss,
- signal to noise ratio (SNR),
- received signal strength indication (RSSI),
- bit error ratio (BER),
- security level,
- etc.

For the pilot implementation basic three monitored system parameters were chosen:

- signal to noise ratio,
- packet latency,
- packet loss.

In case of further implementation it will be possible to include other system parameters if relevant impact is identified.
Implemented decision algorithm supports appropriate access wireless service selection. It is based on application of relevant data requirements recorded in the “decisions tables”. Current status of available telecommunications technologies including the one in use must be continuously available. Cost of each applied access wireless telecommunication service use to be required to be taken in account, as well.

Decision to implement described simplified “Extended PBM” approach was done on based on evaluation of currently available research R&D man power resources. Full adaptive version described below was out of team capacity as well as of allocated resources. With this implemented version was successfully tested this “extended PBM approach”. System successfully passed test scenarios for verification its basic functionalities. Results of measured times needed for the second generation handover are presented in the Table 1.

Project DOTEK was successfully finalized and obtained results were integrated into existing on-board unit (OBU) tested with four telematic applications implemented - EFC, fleet management, e-Call and navigation. Results – i.e. developed software has got modular structure, and, therefore it can be integrated into other compatible systems. Correctly integrated modules can provide relevant management of applied communication solutions. Presented pilot implementation, as presented in Table 1 handover time, is applicable in wide range of transport telematics solutions.

### Table 1. Results of test scenario - time of handover

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Handover time [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>137</td>
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<td>3</td>
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<td>4</td>
<td>108</td>
</tr>
<tr>
<td>5</td>
<td>362</td>
</tr>
</tbody>
</table>

### 6. Adaptive decision process

Below presented approach can be understood as the “conservative” approach based on Bayes statistics with well known limits given by CPU capacity consuming complex mathematical implementations. Authors are driven by fact that applied services are operated as wireless access solutions with parameters not being available in the terrestrial solutions (like SNR). Complex mathematical solution can require remarkable capacity of the applied CPU. It could be expected that combination of classical mathematical solution with approach like POETRY can appear. However, dynamically increasing CPU power of communication micro-chip systems will diminish requirement on reduction of CPU capacity needs and complex statistical mathematical approach will be kept at least for more demanding alternatives.

Following paragraphs describe our approach to the decision processes. Proposed methodology is based on following principles - see [22] or [23]:

- Measured parameters are processed by Kalman filter. Such process separates reasonable part of present noise and also allows prediction of the individual parameters in near future behavior.

Set of measured parameters is extended by deterministic parameters like identification communicated with tall collection, economical parameter, corporate policy etc. All together it is presented as parameters vector $x$.

Based on time lines of vector $x$ it is feasible to classify the best possible technology selection. Classification algorithm is trained using time lines of training vectors $x$ extended by assignment to the relevant class, i.e. selected path.

Success of classification is related to the size and quality of the training data lines.

This solution does not necessarily require 2HL control system with the other layers ones, nevertheless, more stable, efficient and precise decision is obtained if such communication is at least partially possible.

Let us define the classification problem as an allocation of the feature vector:

$$x \in \mathbb{R}^D$$


to one of the $C$ mutually exclusive classes knowing that the class of $x$ takes the value in

$$\Omega = \{\omega_1, \ldots, \omega_C\}$$

with probabilities $P(\omega_1), \ldots, P(\omega_C)$, and $x$ is a realization of a random vector characterized by a conditional probability density function.
This allocation means the selection of best fitted telecommunication technology based on knowledge of x vector. 

A non-parametric estimate of the \( \omega \)-th class conditional density provided by the kernel method is:

\[
p(x | \omega) = \frac{1}{N_{\omega} \cdot h_{\omega}^D} \sum_{i=1}^{N_{\omega}} K\left( \frac{x - x_{\omega}^i}{h_{\omega}} \right)
\]

(1)

where \( K(\cdot) \) is a kernel function that integrates to one, is a smoothing parameter for \( \omega \)-th class, \( N_{\omega} \) stands for sample count in class \( \omega \) and

\[
x_{\omega}^1, \ldots, x_{N_{\omega}}^\omega
\]

is the independent training data. The density estimate defined by (1) is also called the Parzen window density estimate with the window function \( K(\cdot) \).

Choice of a particular window function is not as important as the proper selection of smoothing parameter. For our case we use the Laplace kernel defined by the following Laplace density function:

\[
f_l(x, \mu, \sigma) = \frac{1}{2 \cdot \sigma} \exp\left( -\frac{|x - \mu|}{\sigma} \right)
\]

(2)

where

\[
x, \mu, \sigma \in \mathbb{R}
\]

The product kernel is used with a vector of smoothing parameters \( h_{\omega} = (h_{\omega}^1, \ldots, h_{\omega}^D) \) for each class \( \omega \). The product kernel density estimate with Laplace kernel is then defined as:

\[
f(x | \omega) = \frac{1}{N_{\omega} \cdot \prod_{j=1}^{D} h_{\omega,j}} \prod_{j=1}^{D} \frac{1}{2 \cdot h_{\omega,j}} \exp\left( -\frac{|x_j - x_{\omega,j}^i|}{h_{\omega,j}} \right)
\]

(3)

Smoothing vectors \( h_{\omega} \) are optimized by a pseudo-likelihood cross-validation method using the Expectation-Maximization (EM) algorithm - see [21].

To rank the features according to their discriminative power the standard between-to within-class variance ratio is employed. This method is based on the assumption that individual features have Gaussian distributions. The feature vector

\[
x \in \mathbb{R}^D
\]

takes value to one of \( C \) mutually exclusive classes

\[
\Omega = \{ \omega_1, \ldots, \omega_C \}
\]

The probabilistic measure of two classes separability for the feature \( d \) (d-th component of feature vector) is defined as:

\[
Q_{ij,d} = \frac{\eta \cdot (\sigma_i + \sigma_j)}{|\mu_i - \mu_j|}
\]

(4)

where \( \omega_i \) and \( \omega_j \) are classes and symbol \( \eta = 3.0 \) denotes the real constant specifying the interval taken into account (probability that observation of normally distributed random variable falls in \( [\mu_i - 3.0 \cdot \sigma, \mu_j + 3.0 \cdot \sigma] \) is 0.998). The smaller is the value of the measure \( Q_{ij,d} \) the better is separation of the inspected classes made by the feature \( d \). For \( Q_{ij,d} < 1 \), both classes are completely separable. The measure is similar to the widely used Fisher criterion.

For multi-class problems, the two-class contributions are accumulated to get a C-class separability measure \( Q(d) \) for the feature \( d \):

\[
Q(d) = \sum_{i=1}^{C} \sum_{j>i}^{C} Q_{ij,d}(d, i, j)
\]

(5)

All the features in the training data are then sorted according to their \( Q(d) \) measures. The function \( Q(d) \) is similar to the significance of the of d-th component of the measured feature vector. The subset of n first features is selected as an output of this individual feature selection method. The drawback of the method is the assumption of unimodality and the fact that just linear separability is taken into account. On the other hand, the individual feature selection method based on the between-to within-class variance ratio is very fast.

Presented classification approach is effectively applicable for relevant decision processes used to select the best possible alternative access from the set of available paths. Decision can provide evaluation of both random as well as deterministic processes and introduced approach enables continuous decision processes parameters training.

Presented method allows solutions implementations with limited information flows between layer 2HL and layers 1HL and CL. Presented solution is, however, open for any future changes in information resources. Such changes can lead to the principal decision processes parameters improvement. Due to its self training procedure of the new information resources integration is smooth and relatively simple.

It is important to stress that optimized number of the representative key performance indicators can lead to the significant reduction of required CPU capacity.

7. Conclusion

Due to regular complexity of telematic services covered areas (wide area coverage, several classes of services
with different system requirements) we focused our afford on wireless access solution designed as seamless switched combination of more independent access solutions of the same or alternative technology.

Decision processes representing basis for adaptability of the communications wireless services are quite rarely resolved and published. Most of present implementations are based on Policy-based Management (PBM). This concept has been traditionally applied in the IP based networking and we can only state its remarkable success. Implemented “Extended PBN based” decision processes were presented as well as principle parameters describing system behavior

Our final goal is, however, based on application of Bayes statistics. Set of measured parameters can be so flexibly extended by deterministic parameters like economical parameter, corporate policy etc. Based on self trained classification processes it is feasible to classify the best possible selection i.e. assigning data vector to one of set of classes. Classification algorithm is trained using time line of training data vectors extended by correct assignment to the relevant class, i.e. selected path.

Optimized number of the representative key performance indicators can, however, principally reduce requirement on CPU capacity. That is the reason why detailed study of each applied telecommunications technology has been accomplished in our laboratory to identify specific representative key performance indicators for each technology potentially applied in the system.

Bibliography