Complex Monitoring of Drivers Safety Based on Object Systems of Informative-Effective Radio Networks

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Abstract. The proposed technology for increasing the efficiency of the monitoring wireless networks of driver safety based on object systems of information-efficient radio networks. For efficient and accurate compact coding and recovery of samples of monitoring signals and video data frames, compression of signals and video signals using a signal approach is proposed. According to this approach, the amplitude-time or numerical parameters of the most informative readings of signals and video signals are determined in the rate of input of monitoring data. These are extrema and inflection points or points of change in the movement of the curve. For crypto-protection of monitoring data arrays by processing means of object and on-board systems of monitoring networks, it is proposed to use one-time ciphers, which are rules and parameters for generating crypto-resistant pseudo-random data arrays of a certain length or volume. These rules and parameters are known only to the transmitting subscriber and the receiving subscriber of information packets and are used by network subscribers in the process of lossy and lossless data compression, in the process of forming crypto-resistant and interference-resistant information packets of limited duration with increased information capacity. Energy-efficient transmission of data packets is based on increasing the information efficiency of facilities and on-board systems for monitoring the safety of drivers. Algorithms of operational adaptive filtering of signals are considered. Due to the minimization of computational operations, algorithms for compact data coding with controlled information loss are optimized for coding speed and accuracy.

Keywords: driver safety monitoring, object system, wireless monitoring network, pseudo-random data arrays.

1 Ways to solve the problems of operational monitoring of the driver safety and checkup of their functional states.

Ensuring the drivers and passengers safety of vehicles requires solving a complex of tasks of remote monitoring of the current driver conditions. These tasks are related to the continuous monitoring of the driver's safety and the monitoring of his functional or operational status. To date, various approaches, systems and devices for ensuring the drivers safety are known [1, 2, 4-10]. The service of notifying and calling specialized services using mobile communications is common [3, 11-16]. To monitor the working condition of drivers, a large number of vehicle manufacturers monitor their actions using various sensors installed in the car control system, perform video monitoring of the driver's eyes, etc. Simple devices are known that warn of driver fatigue and sleepiness [4,8].

A radical solution the tasks of drivers safety monitoring is the placement directly on drivers of object systems (OS) of wireless networks [2] for continuous and long-term control of signals and images during driving. Monitoring data (signals from sensors and frames of video data from video modules), driver messages (normal/abnormal type signals, voice messages) are entered, processed, coded, encrypted and transmit-ted to the local and central server of a wireless monitoring network. In order to cover the driver's OS communication within large areas (on highways, in regions, settlements) as wireless networks, it is advisable to use widely distributed LTE and 5G mobile networks, as well as specialized networks based on Wi-Fi and fiber optic lines.

In these networks, an important element is the local central stations of the monitor-ing network, which in experimental networks can be implemented on the basis of a personal computer. Central stations (CS) are connected via various communication channels to the central server of the monitoring network. Received current data on the drivers conditions are stored in remote databases and are the basis for determining the reliable conditions of road users.

2 Monitoring of driver safety and their functional states by the object systems of informative effective radio networks.

The article proposes an information technology for the implementation of operational monitoring of driver safety and control of their functional states using portable operating systems. To monitor biomechanical and biomedical signals, the driver can use a ring, bracelet, or specialized belt. Biomechanical data is transmitted to the OS from the accelerometer sensor. Depending on the sensors informativeness, data of pulse (heart) rhythm, breathing rhythm, or data from Holter monitoring of electro-cardio signals are sent to the OS. One of the electro-cardio signals is aimed at receiving an informative signal about the driver's breathing.

In the future, it is planned to monitor the low-frequency signal taken from the frontal part of the driver's head using a cap with specialized electrodes. It is also advisable to monitor the condition of the driver's eyes. All these monitoring data using wireless means are transmitted to the OS of the wireless monitoring network. To monitor the safety of the driver, as a rule, a specialized button is used, after pressing which an SOS signal and voice messages are transmitted to the central server of the monitoring network. It is also desirable to transmit video footage of the situation with the driver or a short video clip. Obviously, in the future, organizational measures related to ensuring the safety of the driver and passengers should be carried out.

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The main task of the monitoring network is to provide evidence-based monitoring of the driver's safety and functional status, followed by the provision of reliable and protected primary information to remote experts. It includes samples of monitoring signals and data, voice messages, frames of video data, videos that reliably characterize the current situation with the driver. Depending on the location of the car and the driver (highway, route, settlement, remote region), the OS interacts with the CS, which performs the functions of a local server and a relay of monitoring data from many OS to the central server. In large settlements, as a rule, OS and corresponding CAs form cellular networks. To organize the safety of the driver in remote regions, it is necessary to use a specialized car transceiver, which is a subscriber (subscriber station) of an extensive monitoring network. Remote automotive subscriber stations can act as a repeater of monitoring data packets from neighboring automotive subscriber stations. In this way, a relay link of monitoring data from remote cars in sparsely populated regions is formed. The effectiveness of the driver safety monitoring network is significantly dependent on the performance of OS processing tools and a set of complementary algorithms for entering, processing, encoding and encrypting monitoring data by the OS processor, and transmitting packets to a remote CS. In fact, the OS is a converter of incoming streams of monitoring data into output packets of reliable information that are crypto-resistant and protected from channel interference. Long-term operation from autonomous power sources, reliable, crypto-resistant and interference-free transmission of monitoring data from drivers to remote databases and cloud environments are important for the OS. Considering the presence of noise in the measuring links of the sensors, the presence of mechanical influences from the movement of the car, it is important to adapt the algorithms for entering, processing and coding samples of monitoring signals to the level of input noise. That is, it is important in the rate of input of signals, in the process of filtering and compression of signals, it is necessary to clearly distinguish areas of signals that are free of noise (reliable data) and areas affected by noise (unreliable data). It is obvious that reliable sections of monitoring signals should be coded more accurately and qualitatively, and unreliable sections should be coded as concisely as possible. It should be noted that OS processors perform an analysis of the reliability of entered monitoring data, provide compact coding of monitoring data without losing their informativeness, as well as encryption of data to be stored and transmitted over various communication channels. In fact, crypto packets of monitoring data are transmitted in the communication channels in the form of compressed and encrypted pseudo-chaotic data.

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In order to receive and decode cryptographic packets of data, the corresponding subscribers of the monitoring network (central stations, central server of the monitoring network) must possess a set of session and personal keys. After decoding encrypted data, experts receive primary and secondary data (results of processing and express analysis of reliable samples of monitoring signals, sensor data, voice messages, video data frames). On the basis of the received information, evidence-based monitoring of the safety and working conditions of a large number of drivers is achieved.

The effectiveness of the OS functioning is influenced by data protection algorithms, crypto-resistant data coding and the formation or selection of channel sequences of information packets taking into account the level of interference in the radio line "subscriber - transfer of packets - subscriber-receiver of packets". Accordingly, taking into account the long-term operation from autonomous power sources and the transmission of reliable and accurate monitoring data, the processing tools of the OS at the origin of network flows must implement a set of algorithms optimized for speed and accuracy of processing, coding, encryption and transmission of various data (signals, video data frames, video clips).

In general, monitoring signals and video signals are characterized by minimum and maximum values of amplitude and frequency parameters, respectively $X_{\min}$, $X_{\max}$, $f_{\min}$, $f_{\max}$. The most informative (essential) readings of signals or pixels of video signals are extrema and inflection points (points of change in the convexity of the contour curve). In addition to amplitude-time values, essential samples (ES) of signals or essential pixels (EP) of video signals are characterized by additional parameters, such as the current input signal-to-noise ratio in the vicinity of ES (EP) and parameters of the current dynamics of bypass signals and video signals [5], where the current estimate of the value of the input signal/noise ratio in the vicinity of the EC (EP), the current significant sample of the filtered signal, the current input sample of the signal with noise and i = 1,2,3,… is the number of the current sample. It should be noted that when video data frames are entered, arrays of R-, G- and B-frames are formed. The set of pixels of the latter horizontally and vertically form a video signal. The current parameters of the dynamics of bypass signals and video signals are characterized by the current difference between neighboring samples of the filtered signal or the difference between neighboring ES (EP) . For reliable input of the signal, its sampling frequency is chosen to be significantly increased, taking into account the expression , where k > 5...10 is the factor of increasing the sampling frequency, taking into account the parameters of the input low-pass filter and the requirements for the reliability of the lower bits of the analog-to-digital converter (ADC), fdN is the sampling frequency of the signal according to research Nyquist [5], fmax is the highest informative frequency of the signal spectrum. At the maximum number of bits of the analog-to-digital converter bit. . The parameters of the indicators of the implementation of adaptive filtering are determined depending on the operationally calculated current steepness of the signal in relation to the maximum expected (preset) steepness, i.e. . It should be noted that any filtering of signals, or more precisely, a filtering algorithm, introduces distortions inherent in this algorithm. Therefore, during filtering, it is important to obtain filtered readings of signals that are subject to further compression and encryption with minimal computational costs and distortions. In addition to filtered data for the most informative readings, which are extrema and inflection points, it is important to assess the level of input noise, which will enable researchers to highlight the most reliable areas of signals (also to identify areas of signals distorted by noise, in these areas the results of calculations and analysis are unreliable) . From the point of view of speed and accuracy of implementation of signal filtering, median filtering is effective. Studies have shown that median filtering in the vicinity of current signal extrema (maximum or minimum values on the curve) distorts the extrema (clips them). Therefore, in the vicinity of the extrema, for example +/- 4-6 samples in front and behind the extremum, it is necessary to carry out a moving average (we calculate the value of the moving average at the beginning of adaptive filtering, since in order to search for extrema on the filtered curve, it is necessary to determine the value XiF -Xi-1F with the sign (extremum is the value of the value of X when the sign of the difference XiF -Xi-1F changed or became equal to 0. When there is an increasing curve - the sign of the difference XiF -Xi-1F is "+"), when the curve is falling - the sign is "-", when the curve then is equal - the difference XiF -Xi-1F and the change of "+" or "-" to zero is also a sign of an extrema).

3 Description of algorithms for operational adaptive filtering of signals and video signals.

The moving average algorithm is algorithm 1: 1. We take the current three read-ings, average them, and the result will correspond to the average (second) initial read-ing. 2. We make a shift by one input sample, that is, the first sample is discarded, the 2nd, 3rd and 4th input counts are subject to processing. We average and the result will correspond to the 3rd count. Etc.

The median filtering algorithm with an adaptive averaging window is algorithm 2: 1. We take a sequence that contains, for example, 8-12 input samples. We perform a moving average and look for an extremum on the filtered curve based on a change in the sign or state of the difference readings (see p. 5).

2. If an extremum is detected, then we select the neighborhood of the signal around the extremum, for example, 4 counts to the left and right of the extremum, and the results of sliding smoothing in this neighborhood will be the initial data.

2.1. On other sections of the input signal sequence, we perform median filtering with an adaptive analysis and processing window: for the current sample, we determine the value of the absolute difference between the current samples. This difference can be calculated on filtered readings with a moving average. Having a number - select the range of the analysis window: divide the dynamic range of the signal into 4 sub-ranges - 1) greater than or equal to 0 - less than or equal to 0.25 Amax; 2) more than 0.25 Amax - less than or equal to 0.5 Amax; 3) more than 0.5Amax - less than or equal to 0.75Amax; 4) greater than 0.75 Amax - less than or equal to Amax. Accordingly, the range of the analysis window will be as follows: for the range of 1 - 9 input samples; for ... 2 – 7 samples, for 3 ... 5 samples; for range 4 – 3 samples. Having a suitable range of readings, we look for the median, for example, we arrange the samples in ascending or descending order and find the central reading and its amplitude, and also determine the amplitudes of neighboring samples to the right and left. We average these 3 counts and the result is the output filtered sample for the current input sample.

2.2. We make a shift and return to the execution of point 1.3.

3. If there is no extremum, then we perform adaptive median filtering (point 2.1).

The median filtering algorithm with an adaptive averaging window is algorithm 3. We perform the same as in the previous algorithm, but we only search for the median (that is, we do not average the readings that are in the neighborhood of the median) and this median is the output filtered sample.

In the process of inputting data from objects of long-term monitoring, it is important to control the input conditions of signals and video signals and the degree of their distortion by noise and interference. After filtering and compressing the signals, data on the optimization of input data processing are recorded in the service information: signal fragments (video signals) free of interference are coded qualitatively, that is, with an increased frequency of data input and the maximum necessary number of ADC bits, and areas with noise are identified, filtered by simplified algorithms, thinned out and coded less accurately. For a more detailed analysis of the reliability of the input of signal samples, the value ΔX_i^N is analyzed on the correspondingly determined sections of the signals (for example, on the interval of the duration of informative signal complexes or segments of a given duration in the vicinity of extremes and inflection points) or over the duration of the entire sequence of monitoring data. After filtering the signals, the indicator is used in the process of compressed coding of the amplitude-time parameters of the most informative, significant signal samples. Taking into account the specified values ΔX_i^N when encoding data with permissible information loss, the number of valid bits is calculated for each significant sample of the current signal sequence. On the basis of the received data, noise-free areas of signals and areas of signals with different levels of input noise are determined and coded. For ease of coding, taking into account the specifics of applied research, it is advisable to define and code noise-free (reliable) and noise-distorted (less reliable) areas of signals. The results of coding by object systems of monitoring networks are transmitted to the central station of the radio network for a more detailed analysis of signal sequences and final decision-making. Also, according to the commands of the central station, on request, object systems can transmit primary data without filtering. It should be noted that signal shape distortion is significantly affected by signal filtering methods and algorithms. Distortions of the shape of the curve of an analog signal also significantly depend on the selection of the sampling frequency of the analog signal and the metrological characteristics of the ADC.

In order to quickly and accurately filter signals depending on the steepness of the signal among the readings falling into the current analysis and data processing window, it is advisable to identify the largest and smallest amplitude values of the input readings by the method of comparing the amplitude values of the current readings and not take them into account in the further averaging of the data or search medians Accordingly, the number of readings that affect the filtering result is limited, for example 3 or 5, and characterize the trend of the change in the signal envelope. The result of averaging the remaining samples in the current window of analysis and data processing, which are close to the median in amplitude, is the result of filtering and is determined by the expression $X_i^F = (X_b^N + X_c^N + \ldots + X_d^N)/l_i$: where X_b^N , X_c^N , X_d^N is the selected number l_i of input samples with noises that are close to the median in amplitude, $l_i < l_a$, $l_a -$ the size of the analysis window and averaging of input samples (depending on the steepness of the signal $l_a = 3,5,7,9$).

In order to minimize computing operations in the process of processing, coding and transmitting long-term monitoring data, it is important to organize compact coding with manageable (controlled) loss of information of measurement signals, video data (frames of moving and still images), as well as express analysis of input data from a single point of view for operational detection of the most informative arrays of monitoring data and prompt transmission to the central server of the monitoring network.

Since important monitoring data are entered in the form of signals and video signals, in the process of processing and encoding input data, it is important to identify the most informative and reliable readings of bypass signals (video signals), that is, ES or EP. The accuracy of the coding of the amplitude-time parameters of the ES (EP) depends significantly on the features of applied research, data input conditions (absence or presence of noise in the measuring links of object systems, presence of vibrations, etc.), functional orientation of object systems of computer networks and is selected adaptively, for example, among the following encoding modes of signal samples:

1) Accurate coding of the amplitude values of extremes with the maximum number of bits and the maximum signal frequency (this mode is used to ensure reliable and accurate information flows in the network).

2) Accurate coding of ES and intermediate ES parameters on the most informative signal sections with an increased polling frequency.

3) Less accurate coding of the amplitude values of extremes and some ES –IP with a smaller number of ADC bits and a minimum polling frequency, while low-amplitude extrema and some ES–E nearby are ignored, taking into account the minimal distortion of the visual characteristics of the bypass signal (applied when encoding areas of signals with noise).

4) Less accurate coding of extreme parameters (to minimize information flows).

Accordingly, when inputting and processing signals, the amplitude-time characteristics of the most informative readings of signals and video signals, including global and local extrema and signal inflection points, are quickly determined and compactly encoded. The basis of compression and high-quality restoration of signals is the preservation of the characteristics of bypass signals, taking into account the requirements and features of applied tasks, fields of application of adaptive data coding algorithms. At the same time, in the process of compression of ES (EP) parameters with admissible (controlled) loss of information, it is expedient to quickly determine the most informative (noise-free) sections of the signal, on which the ES (EP) parameters are coded as accurately as possible, and less informative sections with noise, on which the maximum data compression. Accordingly, the ES (EP) of noisy areas are subject to minor distortion, and when restoring bypass signals due to the operational classification of signal areas, the formation of a message for researchers (experts) about the type of curve (reliable/less reliable) is ensured. In order to optimize the coding of signals with acceptable information loss, it is advisable to introduce several modes of ES (EP) coding, for example, with high accuracy of coding of ES (EP) parameters, that is, without signal filtering (any filtering of signals leads to distortion of the envelope), with adaptive filtering signals, with limited accuracy of ES (EP) coding (for example, with a smaller number of ADC bits), with the formation of a minimum number of ES (EP), i.e., in this mode, maximum data compression is achieved with permissible information loss. When coding video signals which are formed by video sensors in video data frames (by rows and by columns) it is important to accurately transmit the amplitude-number parameters of extremes and inflection points of video signals. As a result, when decoding compressed video data (with permissible losses and without losses), contours of video signals in moving and still video frames are accurately restored, which is the basis for reliable reproduction of encoded video data.

In the case of using adaptive filtering, after filtering in the process of operational processing and coding of signals based on the analysis of the signs of the difference values ΔX_i^F and ΔX_i^F , the amplitude-time parameters of the ES of the bypass signals are determined, including the extrema and the inflection points of the curve, where, for example, $\Delta X_i^F = X_i^F - X_{i-1}^F$ the current increment of the neighboring samples X_i^F and X_{i-1}^F the filtered signal, $i = \overline{1, v}$ numbering of the input counts of the current signal sample, v - the maximum number of samples that accumulate in the RAM of the processor module of the object system. Depending on the operationally determined mediated estimates of the input signal/noise ratio in the vicinity of the ES $\Delta X_{CBi}^N = \left| X_{CBi}^N - X_i \right|$ and depending on the conditions $\Delta X_{CBi}^N \le \delta_d^N$ or $\Delta X_{CBi}^N > \delta_d^N$, compressed arrays of the difference amplitude-time parameters of the SV signals are formed. A section of the signal formed by two or more neighboring SVs, for which the condition $\Delta X_{CBi}^N < \delta_d^N$ is fulfilled, is considered to be free of noise. Accordingly, the signal samples form sequences of signal sections free of noise (reliable signal sections) or signal sections distorted by noise (less reliable signal sections). Based on the adaptation of input data coding depending on the quality of data input (reliable/less reliable parts of the signals), accurate (with a larger number of ADC bits $q_{\max}$) or less accurate (with a smaller number of ADC bits $q_{\min}$) coding of the amplitude parameters of ES signals is carried out.

Conclusion

Thus, a significant advantage of the algorithm for compact coding of signal readings and video signals using a signal approach is the fact that in the process of analog signal compression, a reasoned decision is made about the accuracy of coding of the most informative signal samples (video signals), which are used on the receiving side to accurately restore contours analog signals. Due to the minimization of computational operations, algorithms for compact data coding with controlled information loss are optimized for coding speed and accuracy.

After implementation of operational adaptive filtering of signal readings and determination of amplitude-time parameters of extremum ES, we obtain ES parameters on signal sections with noise. The ES parameters, which refer to clean areas, are subject to further specification.

To determine the median based on comparisons of the amplitude values of the corresponding samples, the samples are arranged in the data analysis and processing window, for example, by increasing amplitude. After ordering the samples, the central sample among is determined. Depending on the type of coding of monitoring data, including coding with filtering, coding without filtering, coding using , encoding using and the stream of output compact data is encoded in the form of a stream of service and informative monitoring data. The resulting data stream after the intersection of signal samples and video data frames is subject to operational lossless compression and protection of compressed data arrays using one-time ciphers [2,5,6].

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