Technique for encoding clustered transformants in differentially-normalized space

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Abstract

The article shows that one of the main purposes of projects for the development of informatization of the state is the proper provision of the necessary information to the centers of analysis and decision-making. It is important to comply with the requirements for the timeliness, reliability and security of information delivery processes. The necessity for the formation of homogeneity spaces for the group of transformants of the general video stream for the implementation of the possibility of accounting for inter-transformant dependencies in the SPD of arrays of spectral elements is substantiated. A model for constructing homogeneity spaces (clusters) from the transformant group based on the power of the SP by the number of spectral SP has been developed. This creates the conditions for the implementation of the compression procedure with the additional removal of the amount of inter-transformant redundancy in the SPD-transformant.

Keywords

video encoding, transformant, compression, reduction

1. Introduction

One of the main objectives of state informatization projects is to adequately provide decision-making and analysis centers with necessary information [1, 2]. It is crucial to meet the requirements for timeliness, reliability, and security in the information delivery processes [3, 4, 5]. In modern conditions, monitoring objects are often located far from the analysis centers that assess their condition. This necessitates the development of remote information collection and transmission means using various technological solutions. Unmanned systems have become particularly in demand [6]. This is due to several advantages that these systems offer for monitoring hard-to-reach areas or regions experiencing emergencies [7, 8]. Consequently, this approach to information provision is actively utilized by governmental organizations and relevant ministries. Therefore, unmanned systems (UAS) play an important role in the overall chain of organizing information support for decision-making subsystems. As a result, certain requirements are set regarding the performance characteristics of UAS, such as the generation of the initial format of digitized images, processing, and transmission of information [9, 10].

It is important to note that these UAS characteristics depend on many factors, including the external conditions of monitoring and internal factors such as the energy capacity and payload of the UAS [11, 12,

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13, 14, 15]. In practice, such factors often limit the capabilities of the UAS telecommunication equipment. Consequently, the timeliness and reliability of information transmission are feasible only for lower-level image formats [16, 17].

On the other hand, the information analysis procedure, including the use of intelligent analysis, calls for implementing higher-level image formats on UAS [18, 19, 20]. Clearly, a contradiction arises regarding the discrepancy between acceptable and necessary levels of image formats for unmanned systems [21, 22, 23]. This increases the risk of losing access and reliability of the transmitted information.

Localization of such conflicts can be achieved by appropriately reducing the information load created by digitized images. Specific methods aimed at reducing redundancy are used for this purpose [21, 22, 23]. These methods are referred to as image compression technologies. Therefore, enhancing the image format level for UAS based on compression methods is a relevant scientific and practical task.

2. The main material presentation

Currently, there are established standards for implementing image compression, with the majority being based on reducing redundancy in the spectral space of individual fragments. These methods are built by considering certain characteristics in the description of image fragments. Compression processes are implemented by predicting the presence of: fragments with low visual sensitivity; and fragments with a high level of correlation dependencies. In the spectral space, these characteristics of fragments are manifested as follows: transformation of range intervals towards a limited number of low-frequency components; presence of sequences of spectral components with insignificant deviation of range interval—spectral sub-bands $sb(t;\delta)_\alpha$ [24, 25, 26, 27, 28, 29, 30, 31].

The existence of these characteristics forms the basis for constructing compression methods in the spectral-parametric description of transformants (SPOT). This representation is formed by a set of parameters $\{\lambda(t;\delta)_\alpha; \mathrm{sign}(t;\delta)_\alpha\}$ for each spectral sub-band (SB) $sb(t;\delta)_\alpha$, which are determined by the zig-zag direction through the two-dimensional transformant. Different approaches are used to process the set of parameters $\lambda(t;\delta)_\alpha; \mathrm{sign}(t;\delta)_\alpha$ [24, 25, 26, 27].

Most of these approaches take into account local statistical dependencies either for individual components $\lambda(t;\delta)_\alpha$ and $s(t;\delta)_\alpha$ independently or try to consider the dependency between these components in pairs $loc(t;\delta)_\alpha$. Thus, higher-order statistical dependencies are insufficiently tested in redundancy reduction processes. Moreover, the dependencies between fragments in a group of video frames are often not considered. This lack of consideration decreases the effectiveness of image compression methods and reduces the opportunities to address the contradictions. Therefore, the purpose of this article is to develop image compression methods based on their spectral-parametric description, considering higher-order dependencies.

3. Development of a model for representing the transformant in spectral-parametric description

As a result of performing discrete cosine transformation (DCT) on an image fragment, an array of spectral components $Y(t;\delta)^{(1)}$ is formed. Here, t is the index of the spectral component array within the general video stream group, and δ represents the quantization parameter. Accordingly, to construct its spectral-parametric description, a sub-band discretization process is implemented by constructing vectors $loc(t;\delta)_\alpha$ of two components $loc(t;\delta)_\alpha = \{\lambda(t;\delta)_\alpha; sign(t;\delta)_\alpha\}$: $\lambda(t;\delta)_\alpha$ is the length of the spectral sub-bands; $sign(t;\delta)_\alpha$ is the level of spectral sub-bands.

The number $n(t;\delta)_{sb}$ of vectors $loc(t;\delta)_\alpha$ depends on the number of spectral sub-bands within the transformant. In turn, the number of spectral sub-bands depends on the complexity of the SPOT structure. In the general case, the values of $n(t;\delta)_{sb}$ for each spectral component array within the video stream group will be different, $n(t;\delta)_{sb} = var$. The value $n(t;\delta)_{sb}$ for the t-th transformant also depends on the level $r(t)_{inf}$ of informativeness of the original video fragment and the quantization strategy $F(t;\delta)_{kvt}$ for the spectral space. Hence, in the general case, we have the following functional relationship:

$$n(t;\delta)_{sb} = fun(r(t)_{inf}; F(t;\delta)_{kvt}). \quad (1)$$

The informativeness $r(t)_{inf}$ of video fragments is often considered in three levels. Each level is determined by the concentration of fine details within the video fragment (VF). Accordingly, we have VFs with low, medium, and high detail density. Through the conducted procedure, the initial array $Y(t;\delta)^{(1)}$ is transformed into SPOT $P(t;\delta)$. In this description, each of the columns forms a vector-component of the SPOT: the left column represents the component $L(t;\delta)^{(1)}$ of the lengths of the spectral sub-bands $L(t;\delta) = \{\lambda(t;\delta)_1; \ldots; \lambda(t;\delta)_{n(t;\delta)_{sb}}\}$; the right column represents the component $S(t;\delta)^{(1)}$ of the levels of the spectral sub-bands $S(t;\delta) = \{sign(t;\delta)_1; \ldots; sign(t;\delta)_{n(t;\delta)_{sb}}\}$.

It is clear that, to account for the dependencies within the SPOT-transformants group, their corresponding features must be considered. Therefore, it is necessary to ensure their homogeneity. This will enable the compression procedure to be implemented with a higher level of redundancy reduction. The solution approach involves clustering the SPOT-transformants within the video stream group by the parameter $n(t;\delta)_{sb}$. Thus, it is proposed to implement the features among SPOT-transformants within the group during compression. To do this, homogeneous spaces are first formed. Clusters include spectral element arrays with homogeneous SPOT parameters. The process of recombining the group of transformants into homogeneous clusters is organized by the parameter $n(t;\delta)_{sb}$ – the power of the spectral-parametric description of the transformant by the number of spectral sub-bands. Then, if we denote a group of T spectral element arrays in the SPOT as $\mathbb{P}(\delta)_T$, $\mathbb{P}(\delta)_T = \{P(t;\delta); \ldots; P(T;\delta)\}$, a sequence $n(\delta)_{sb}$ is formed, $n(\delta)_{sb} = \{n(t;\delta)_{sb}\}_{t=1}^{T}$. The power $n(t;\delta)_{sb}$ of SPOT, according to formula (1), depends on the quantization mode level δ and the informativeness $r(t)$ of the image fragment. Thus, constructing homogeneous spaces from the transformants is proposed based on the power of their SPOT.

Constructing homogeneous spaces from transformants by the power of their SPOT allows us to realize the inter-transformant features. Such clusters are denoted as $\Omega(\delta;\lambda)$, where λ is the cluster marker. Each such cluster is characterized by a value of $n(t;\delta)$. The current transformant $P(t;\delta)$ in SPOT is then added to the cluster $\Omega(\delta;\lambda)$, that is, $P(\xi;\delta;\lambda) := P(t;\delta)$, if the condition is satisfied: $sign(n(t;\delta)_{sb} - n(t;\delta)_\lambda) = 0 \Rightarrow n(t;\delta)_\lambda := |\Omega(\delta;\lambda)| + 1,\ t = 1, \ldots, T$.

Here: $P(\xi;\delta;\lambda)$ is the ξ-th transformant in the cluster $\Omega(\delta;\lambda)$, and $n(\delta;\lambda)$ is the number of transformants in the λ-th homogeneity space. The total number of clusters for a group of transformants in SPOT equals $\Lambda,\ \lambda = 1, \Lambda$.

Clustering ensures that the number of spectral sub-band parameters is balanced for adequately detecting dependencies in the sequence of transformants. Accordingly, dividing the transformant group into homogeneous spaces enables implementing the procedure for accounting for dynamic dependencies in the inter-transformant SPOT space. This approach allows identifying features among the components of parameters $\lambda(t;\delta)_\alpha$ and $sign(t;\delta)_\alpha$ of SP slices: slice $L(\delta)_\alpha^{(1)}$ of spectral sub-band lengths, and slice $S(\delta)_\alpha^{(1)}$ of spectral sub-band levels.

4. Creation of a method for binary block coding of structural components of spectral-parametric description

Let's consider the processing of transformants within a specific k-th cluster. In the process of encoding the set of transformants $P(\xi;\delta;\lambda)$ belonging to cluster λ, the following aspects need to be taken into account:

- each transformant $P(\xi;\delta;\lambda)$ is represented in a spectral-parametric description,

  $$P(\xi;\delta;\lambda) = \{L(\xi;\delta;\lambda),\ S(\xi;\delta;\lambda)\},$$

  where $L(\xi;\delta;\lambda)$ and $S(\xi;\delta;\lambda)$ are structural components of the SPOT of the ξ-th transformant in the λ-th cluster;

- each transformant $P(\xi;\delta;\lambda),\ \xi = 1,\dots,|P(\delta;\lambda)|$ in this cluster contains the same number;
- there are dependencies in the structural-parametric SP slices $L(\xi;\lambda)$ and $S(\xi;\lambda)$:

$$L(\xi;\lambda) = \{\mu(\xi_1;\lambda), \mu(\xi_2;\lambda), \dots, \mu(\xi_n;\lambda)\},$$

$$S(\xi;\lambda) = \{\mathrm{sign}(\xi_1;\lambda), \mathrm{sign}(\xi_2;\lambda), \dots, \mathrm{sign}(\xi_n;\lambda)\}.$$

For the set of transformants within the λ-th cluster, such dependencies are due to the homogeneity of the properties for the corresponding spectral sub-bands. To account for this feature, it is proposed to determine the upper and lower bounds of the defined intervals for the components of the respective SP slices $L(\xi;\lambda)$ and $S(\xi;\lambda)$:

$$\max(L(\xi;\lambda)), \quad \max(\mathrm{sign}(\xi;\lambda)),$$

$$\min(L(\xi;\lambda)), \quad \min(\mathrm{sign}(\xi;\lambda)).$$

Considering the constraints $\min(L(\xi;\lambda))$, $\min(S(\xi;\lambda))$ in the direction of the slices, the corresponding actual values of the components $L(\xi;\lambda)$ and $S(\xi;\lambda)$ of the SP slices will belong to smaller intervals $\mathrm{diap}(L(\xi;\lambda))$, $\mathrm{diap}(S(\xi;\lambda))$ of definiteness. In this case, their values will be truncated from below (normalized). To describe the significance of reducing the magnitudes of $\mathrm{diap}(L(\xi;\lambda))$, $\mathrm{diap}(S(\xi;\lambda))$, it is proposed to use coefficients $k(L(\xi;\lambda))$ and $k(S(\xi;\lambda))$.

Then, for SP slices within individual clusters, the conditions hold:

$$\mathrm{diap}(L(\xi;\lambda)) < k(L(\xi;\lambda)) \cdot \max\{L(\xi;\lambda)\}, \quad 0 < k(L(\xi;\lambda)) < 1,$$

$$\mathrm{diap}(S(\xi;\lambda)) < k(S(\xi;\lambda)) \cdot \max\{\mathrm{sign}(\xi;\lambda)\}, \quad 0 < k(S(\xi;\lambda)) < 1.$$

The smaller these parameters are, the shorter the interval of definiteness for the components of the corresponding SP slices will be. The nature of changes in the values of parameters $k(L(\xi;\lambda))$ and $k(S(\xi;\lambda))$ from position q will differ depending on the type of structural-parametric components of SPOT. Since the components of SPOT have different structural origins, we have the following:

1. For components of the structural component $L(\xi;\delta;\lambda)$:

   $$k(L(\xi;\lambda)) \sim \alpha.$$

   At positions of vector $L(\xi;\lambda)$ corresponding to smaller values of α, the length of the definiteness interval of the differential normalized components $L(\xi;\lambda)$ will approach zero.
2. For components of the component $S(\xi;\delta;\lambda)$ of the SPOT transformant:

   $$(1 - k(S(\xi;\lambda))) \sim \beta.$$

   At positions of vector $S(\xi;\lambda)$ corresponding to smaller values of β, the length of the definiteness interval of the differential-normalized components $\mathrm{sign}(\xi;\lambda)$ will be the largest.

Hence, the amount of information $I_d(P(\xi;\delta;\lambda))$ in the transformant $P(\xi;\delta;\lambda)$, represented by the components $L(\xi;\delta;\lambda)$ and $S(\xi;\delta;\lambda)$ of its spectral-parametric description, changes. The value of $I_d(P(\xi;\delta;\lambda))$, depending on the nature of constraints $F(L(\xi;\delta;\lambda))_{iqp}$ and $F(S(\xi;\delta;\lambda))_{iqp}$ in the SPOT components, is described generally as follows:

$$I_d(P(\xi;\delta;\lambda)) = b(\xi;\delta;\lambda) \cdot \log_2(F(L(\xi;\delta;\lambda))_{iqp} \cdot F(S(\xi;\delta;\lambda))_{iqp})$$

Here, the values $F(L(\xi;\delta;\lambda))_{iqp}$ and $F(S(\xi;\delta;\lambda))_{iqp}$ depend on the consideration of additional dependencies for components in the SP slices $L(\xi;\delta)$ and $S(\xi;\delta)$:

$$F(L(\xi;\delta;\lambda))_{iqp} = \begin{cases} \dfrac{\mathrm{diap}(L(\xi;\delta))}{\mathrm{pow}(L(\xi;\delta))}, & \text{if } \mathrm{diap}(L(\xi;\delta)) \geq \min(L(\xi;\lambda)) \\ 1, & \text{otherwise} \end{cases}$$

$$F(S(\xi;\delta;\lambda))_{iqp} = \begin{cases} \dfrac{\text{diap}(S(\xi;\delta))}{\text{pow}(S(\xi;\delta))}, & \text{if diap}(S(\xi;\delta)) \geq \min(S(\xi;\lambda)) \\ 1, & \text{otherwise} \end{cases}$$

Second approach: finding the amount of redundancy $R(loc(\xi;\delta;\lambda))$ per LKM of SPOT when additional constraints are considered on the range of values of components $L(\xi;\delta;\lambda)$ and $S(\xi;\delta;\lambda)$. From here, we can determine the amount of information $I_d(loc(\xi;\delta;\lambda))$ that is on average contained in one LKM $loc(\xi;\delta)$ for the transformant in the spectral-parametric description $P(\xi;\delta;\lambda)$. The following expression is used for this purpose:

$$I_d(loc(\xi;\delta;\lambda)) = b(\xi;\delta;\lambda) \cdot \log_2(F(L(\xi;\delta;\lambda))_{atap} \cdot F(S(\xi;\delta;\lambda))_{atap})$$

Thus, depending on the type of constraints imposed on the components of the SPOT structural components, two approaches can be used to determine redundancy.

First approach: determining the amount of redundancy $R(loc(\xi;\delta;\lambda))$ per LKM of SPOT for the case where additional dependencies on SP slices are not considered. In this case, the value $R(loc(\xi;\delta;\lambda))$ is determined by the following expression:

$$R(loc(\xi;\delta;\lambda)) = 100 \cdot \frac{b(\xi;\delta;\lambda) - \log_2(\text{diap}(L(\xi;\delta;\lambda)) \cdot \text{diap}(S(\xi;\delta;\lambda)))}{b(\xi;\delta;\lambda)}$$

Given this, the value $R(loc(\xi;\delta;\lambda))$ is estimated by the formula:

$$R(loc(\xi;\delta;\lambda)) = 100 \cdot \left(1 - \frac{\log_2(\text{diap}(L(\xi;\delta;\lambda)) \cdot \text{diap}(S(\xi;\delta;\lambda)))}{b(\xi;\delta;\lambda)}\right)$$

In these expressions, the value $b(\xi;\delta;\lambda)$ represents the number of bits on average contained in one spectral sub-band (SSP) for the SPOT of the ξ-th transformant of the λ-th cluster.

$$R(loc(\xi;\delta;\lambda)) = \sum_{a=1}^{M(\xi;\delta)} \frac{1}{M(\xi;\delta)} R_a$$

Thus, the need for forming homogeneous spaces for the group of transformants of the general video stream is substantiated to allow for the accounting of inter-transformant dependencies in the SPOT arrays of spectral elements. This makes it possible to align sub-groups of homogeneous transformants according to the characteristics of their SPOT (number of spectral-SP).

5. Conclusions

1. A model for describing the transformant based on spectral-parametric representation parameters, considering the formation of spectral-SP, has been developed.

2. The necessity of forming homogeneous spaces for groups of transformants of the general video stream has been substantiated to allow for the consideration of inter-transformant dependencies in SPOT arrays of spectral elements. This enables alignment of homogeneous sub-groups of transformants according to the characteristics of their SPOT (number of spectral-SP).

3. A model for constructing homogeneous spaces (clusters) from a group of transformants based on SPOT power by the number of spectral SP has been developed. This creates conditions for implementing the compression procedure with additional removal of inter-transformant redundancy in SPOT-transformants.

4. Models have been created to estimate the amount of redundancy in the SPOT representation of transformants in a cluster, determined by two types of dependencies: spectral-parametric dependencies within the transformants of the cluster; inter-transformant dependencies in the structural-parametric slices of the transformant sequence in the cluster. This allows estimating additional redundancy that can potentially be reduced by considering inter-transformant constraints in the direction of SP slices.

5. A comparative assessment of the characteristic of dynamic change in the bit volume of images in the sequence showed that for peak signal-to-noise ratio levels of 27 dB – 37 dB, the developed compression method provides an average gain of 17% and 11%.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

References

[1] Y. Niu, X. Li, Y. Zhao, R. Ni, An enhanced approach for detecting double jpeg compression with the same quantization matrix, Signal Processing: Image Communication 76 (2019) 89–96.

[2] X. Gao, J. Mou, L. Xiong, Y. Sha, H. Yan, Y. Cao, A fast and efficient multiple images encryption based on single-channel encryption and chaotic system, Nonlinear Dynamics 108 (2022) 613–636.

[3] D. Barannik, V. Barannik, Steganographic coding technology for hiding information in infocommunication systems of critical infrastructure, in: 2022 IEEE 4th International Conference on Advanced Trends in Information Theory (ATIT), Kyiv, Ukraine, 2022, pp. 88–91. doi:10.1109/ATIT58178.2022.10024185.

[4] F. Li, Z. Qi, X. Zhang, C. Qin, Progressive histogram modification for jpeg reversible data hiding, IEEE Transactions on Circuits and Systems for Video Technology 34 (2024) 1241–1254.

[5] R. K. Singh, B. Kumar, D. K. Shaw, D. A. Khan, Level by level image compression-encryption algorithm based on quantum chaos map, Journal of King Saud University - Computer and Information Sciences 33 (2021) 844–851.

[6] T. Belikova, Decoding method of information-psychological destructions in the phonetic space of information resources, in: 2nd IEEE International Conference Advanced Trends in Information Theory (ATIT), Kyiv, 2020, pp. 87–91.

[7] X. Wang, C. Liu, D. Jiang, A novel triple-image encryption and hiding algorithm based on chaos, compressive sensing and 3d dct, Information Sciences 574 (2021) 505–527.

[8] N. Ruzhentsev, et al., Radio-heat contrasts of UAVs and their weather variability at 12 GHz, 20 GHz, 34 GHz, and 94 GHz frequencies, ECTI Transactions on Electrical Engineering, Electronics, and Communications 20 (2022) 163–173. doi:10.37936/ecti-eec.2022202.246878.

[9] J. Anju, R. Shreelekshmi, Secure content-based image retrieval using combined features in cloud, in: Distributed Computing and Internet Technology, 2019, pp. 179–197.

[10] K. Dergachov, et al., GPS usage analysis for angular orientation practical tasks solving, in: Proceedings of the IEEE 9th International Conference on Problems of Infocommunications Science and Technology (PICST), 2022, pp. 187–192. doi:10.1109/PICST57299.2022.10238629.

[11] O. Kulitsa, D. Komolov, D. Zhurbynskyy, Selective method for hiding of video information resource in telecommunication systems based on encryption of energy-significant blocks of reference i-frame, in: 1st International Conference on Advanced Information and Communication Technologies (AICT), 2015, pp. 80–83.

[12] X. Ye, Y. Zhang, X. Xiao, S. Yi, R. Lan, Usability enhanced thumbnail-preserving encryption based on data hiding for jpeg images, IEEE Signal Processing Letters 30 (2023) 793–797.

[13] V. Barannik, N. Barannik, S. Shulgin, V. Barannik, Method of coding subbands of non-homogeneous spectrum of video segments in uneven diagonal space, in: 2022 IEEE 4th International Conference on Advanced Trends in Information Theory (ATIT), Kyiv, Ukraine, 2022, pp. 72–75. doi:10.1109/ATIT58178.2022.10024236.

[14] A. Morales, J. Fierrez, R. Vera-Rodriguez, R. Tolosana, Sensitivenets: Learning agnostic representations with application to face images, IEEE Transactions on Pattern Analysis and Machine Intelligence 43 (2021) 2158–2164.

[15] Q. Bammey, Jade owl: Jpeg 2000 forensics by wavelet offset consistency analysis, in: 2023 8th International Conference on Image, Vision and Computing (ICIVC), 2023.

[16] A. Zemliachenko, N. Ponomarenko, V. Lukin, K. Egiazarian, J. Astola, Still image / video frame lossy compression providing a desired visual quality, Multidimensional Systems and Signal Processing (2015) 22.
[17] V. Barannik, V. Barannik, Binomial-polyadic binary data encoding by quantity of series of ones, in: 2020 IEEE 15th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET), Lviv-Slavske, Ukraine, 2020, pp. 775–780. doi:10.1109/TCSET49122.2020.235540.
[18] V. Barannik, Y. Ryabukha, N. Barannik, D. Barannik, Indirect steganographic embedding method based on modifications of the basis of the polyadic system, in: 2020 IEEE 15th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET), Lviv-Slavske, Ukraine, 2020, pp. 699–702. doi:10.1109/TCSET49122.2020.235522.
[19] V. Barannik, T. Belikova, P. Gurzhii, The model of threats to information and psychological security, taking into account the hidden information destructive impact on the subconscious of adolescents, in: 2019 IEEE International Conference on Advanced Trends in Information Theory (ATIT), Kyiv, Ukraine, 2019, pp. 267–270. doi:10.1109/ATIT49449.2019.9030432.
[20] H. He, Y. Yuan, Y. Ye, H.-M. Tai, F. Chen, Chosen plaintext attack on jpeg image encryption with adaptive key and run consistency, Journal of Visual Communication and Image Representation 90 (2023).
[21] V. V. Barannik, Y. N. Ryabukha, V. V. Tverdokhleb, D. V. Barannik, Methodological basis for constructing a method for compressing of transformants bit representation, based on non-equilibrium positional encoding, in: International Conference on Advanced Information and Communication Technologies, Lviv, Ukraine, 2017, pp. 188–192. doi:10.1109/AIACT.2017.8020096.
[22] D. Lazzarotto, M. Testolina, T. Ebrahimi, Subjective performance evaluation of bitrate allocation strategies for mpeg and jpeg pleno point cloud compression, 2024. ArXiv:2402.04760v2.
[23] V. V. Barannik, M. P. Karpinski, V. V. Tverdokhleb, D. V. Barannik, V. V. Himenko, M. Aleksander, The technology of the video stream intensity controlling based on the bit-planes recombination, in: 2018 IEEE 4th International Symposium on Wireless Systems within the International Conferences on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS-SWS), Lviv, Ukraine, 2018, pp. 25–28. doi:10.1109/IDAACS-SWS.2018.8525560.
[24] X. Sun, Z. Chen, L. Wang, C. He, A lossless image compression and encryption algorithm combining jpeg-ls, neural network and hyperchaotic system, Nonlinear Dynamics 111 (2023) 15445–15475.
[25] V. Barannik, S. Podlesny, D. Tarasenko, D. Barannik, O. Kulitsa, The video stream encoding method in infocommunication systems, in: 2018 14th International Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET), Lviv-Slavske, Ukraine, 2018, pp. 538–541. doi:10.1109/TCSET.2018.8336259.
[26] Q. Xu, K. Sun, C. Cao, C. Zhu, A fast image encryption algorithm based on compressive sensing and hyperchaotic map, Optics and Lasers in Engineering 121 (2019) 203–214.
[27] C. Gudavalli, E. Rosten, L. Nataraj, S. Chandrasekaran, B. S. Manjunath, Seetheseams: Localized detection of seam carving based image forgery in satellite imagery, in: 2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), 2022.
[28] C. Livada, T. Horvat, A. Baumgartner, Novel block sorting and symbol prediction algorithm for pde-based lossless image compression, Applied Sciences 13 (2023) 2–34.
[29] X. Chai, Y. Chen, L. Broyde, A novel chaos-based image encryption algorithm using DNA sequence operations, Optics and Lasers in Engineering 88 (2017) 197–213. doi:10.1016/j.optlaseng.2016.08.009.
[30] H. Zhang, X. qing Wang, Y. jie Sun, X. yuan Wang, A novel method for lossless image compression and encryption based on lwt, spiht and cellular automata, Signal Processing: Image Communication 84 (2020).
[31] V. V. Barannik, N. Kharchenko, V. V. Tverdokhleb, O. Kulitsa, The issue of timely delivery of video traffic with controlled loss of quality, in: 2016 13th International Conference on Modern Problems of Radio Engineering, Telecommunications and Computer Science (TCSET), Lviv, Ukraine, 2016, pp. 902–904. doi:10.1109/TCSET.2016.7452220.