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METHOD FOR QUANTITATIVE CRITERION BASED TRANSFORMATION OF THE VIDEO INFORMATION ALPHABET

Subject of study: *technologies implemented in modern video coding algorithms to ensure the appropriate level of reliability in the conditions of their compact presentation. The goal is to develop a technology for transforming the alphabet of a video information based on a quantitative criterion while ensuring the required quality in networks.* ***Objectives***: *to formulate requirements to video images in dynamic video surveillance systems; to analyze the existing factors leading to an imbalance between the compression and quality characteristics of existing video coding algorithms; to develop a technology for transforming the alphabet of a video information based on a quantitative criterion (attribute) for the best presentation of the encoded data; to develop a mathematical model for the formation of a quantitativeindicator for the transformation of the video images; to analyze the effectiveness of using the developed mathematical model for the formation of a quantitative indicator to provide the required trustworthiness of data for the video information resource; to assess the effectiveness of the developed technology for transforming the original message in terms of a quantitative indicator to ensure the best presentation of the encoded data; to investigate the dynamics of the probabilistic and statistical characteristics of the original message as a result of transformation according to the quantitative criterion of the significance of the elements.* ***The research methods:*** *compression coding methods implemented on the basis of the JPEG algorithms.* ***The research results***: *a new approach has been proposed based on the transformation of the encoded alphabet of data by use of a quantitative criterion. A mathematical model has been developed for the formation of a quantitative attributethat determines the significance of the elements of the original message.* ***Conclusions.*** *A technology has been developed for transforming the alphabet of the original message, which allows creating conditions for a more profitable presentation of the encoded data due to a significant increase in the dynamic range of probabilistic and statistical characteristics for the transformed message while ensuring the required level of video image quality.*

Keywords: *video information resource; transformation; alphabet; quantitative attribute; reliability; coding technologies*.

Introduction

Formulation of the problem. Trends of rapid digital transformation of the modern information space lead to a significant increase in the requirements for information resources. This is due to the fact that the information resource occupies a very important place in the information support system at both state and local levels. It should be noted that an important role in the information system is given to video information resources as a tool for timely prevention and response to relevant crises that arise in society and in the critical infrastructure system as a whole [1-3]. The main sources of video information resources are static (stationary) and dynamic video surveillance systems [4-6]. Representatives of the latter are air monitoring systems (unmanned aerial vehicles). It should be noted, that one of the main problem factors in the use of dynamic video surveillance systems is to limit the bandwidth of wireless data transmission technologies [7-9]. In this regard, the requirements for video information resources are growing [10-12]. The main ones are the following [13-18]:

1. Prompt delivery of video information resources to the end user in order to improve the management of relevant bodies, forces and means to overcome relevant crises that arise in society and in the critical infrastructure system as a whole (ie ensuring timely detection and response to relevant crises) [13, 15, 18];
2. Compact presentation of coded data with the required level of quality [14, 16, 17]. This will ensure the required level of data reliability in terms of bandwidth limitations of wireless data transmission channels, which in turn will allow to give an adequate assessment of the informativeness of the received data of the video information resource.

1. Analysis of recent research and publications

Analysis of recent scientific publications shows that currently actively developing technologies for encoding video information resources, built on the conceptual basis of algorithms of the JPEG platform [18-21]. However, these technologies have a number of problematic factors [22-24]. The main ones are [23 - 28]:

1. Complexity of algorithmic implementation [23, 25]. This is due to the fact that the implementation of algorithms of the JPEG family involves a number of stages of processing, and therefore increases the time required for data processing.

2. In addition to providing sufficiently high compression characteristics, the loss of semantically significant elements of video images is possible, which leads to a decrease in the level of reliability of video information resource data [24, 26 - 28].

Thus, there is an imbalance between the compression characteristics of the JPEG family of algorithms and the required level of reliability of video images [29-31]. Thus, in the JPEG algorithm, the main loss of information (which can lead to a significant loss of the quality level of encoded video images) occurs at the quantization stage [32-35]. That is, a more favorable representation of the encoded data from the standpoint of providing compression characteristics of the algorithm can lead to a significant deterioration in the level of reliability of the reconstructed video image [36-39].

The presence of these problematic factors leads to the need to find new approaches for a more profitable presentation of coded data in terms of ensuring the required level of quality [40-44]. This in turn will create the conditions for a compact representation of the encrypted data.

Therefore, ensuring the required (high) level of qualityvideo images in terms of their compact presentationis an urgent scientific and applied task.

The purpose of the article – development of a method of transformation of the alphabet of video information resource on a quantitative basis for a more favorable presentation of encoded datafrom the standpoint of creating conditions to ensure the necessary compression and quality characteristics.

2. Development of a method for transforming the alphabet of video images by quantitative indicators

Forensuring the required (high) level of qualityvideo images in terms of their compact presentation proposed to develop method of transformation of the alphabet of video information resource on a quantitative basis, which will ensure compliance with the following requirements:

1. Create conditions to ensure the required level of compression characteristics. Accordingly, the developed method should create conditions to ensure an increase in the level of compression characteristics compared to existing methods of encoding video images, ie the following condition must be met:

$$K_{compr_{DM}} \geq K_{compr_{IM}}, \qquad (1)$$

where $K_{compr_{DM}}$ is compression ratio of video images for the developed method;

$K_{compr_{EM}}$ is video compression ratio for existing methods.

2. Ensuring the required (high) level of quality of the reconstructed video image, ie the following condition must be met:

$$MSE_{DM} \to 0, \qquad (2)$$

where MSE_{DM} is standard deviation for the developed method.

Accordingly, the developed method should provide better indicators of the quality of the captured images compared to existing coding methods, ie the following condition must be met:

$$MSE_{DM} \leq MSE_{EM}, \qquad (3)$$

where MSE_{EM} is standard deviation for existing methods.

Next, it is proposed to develop a method of transforming the initial video image on a quantitative basis.

Preparation of the video resource for encoding, ie transformation of the initial video image (hereinafter the message $X(n)$) on a quantitative indicator is proposed to be conducted in two stages:

1st stage: transformation of the alphabet of coded data;

Stage 2: transformation of the initial message $X(n)$.

To transform the original video image (hereinafter the message $X(n)$) in order to ensure a more favorable presentation of coded data, it is proposed to use a quantitative indicator - an indicator of significance $S(x_i)$ elements x_i message $X(n)$, which will take into account the psychovisual redundancy of the encoded video image by taking into account statistical patterns.

The mathematical description of the specified quantitative indicator has the following look:

$$S(x_i) = \frac{P(x_i)}{\sum_{j=1}^{\alpha} \frac{P(x_j)}{D(x_i, x_j)^{\beta}}}, \qquad (4)$$

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where $S(x_i)$ is an indicator of the importance of the elements x_i message $X(n)$;

$P(x_i)$ is the probability of occurrence of elements x_i in the initial message $X(n)$;

x_i is element of the initial message $X(n)$, which is received by the center of the simulated RGB color cube, within which the correlations of the message element are taken into account;

x_j is elements of the initial message $X(n)$, correlations with which are taken into account in the process of forming a significant indicator $S(x_i)$ (elements belonging to the proposed model of the color cube RGB, the center of which is the coded element), $j=\overline{1,\alpha}$;

α is the number of elements of the message, the correlations with which are taken into account to account for psychovisual redundancy;

$D(x_i, x_j)$ is the distance between the elements of the original message $X(n)$.

The structural and functional scheme of the transformation of the initial video image in quantitative terms is shown in Fig. 1.

The initial stage of transformation of the coded video image on a quantitative indicator is the process of taking into account statistical patterns in the message $X(n)$, which is implemented by determining the probability distribution of elements x_i in the initial message $X(n)$.

Thus a set of values of probabilities of occurrence of elements is formed x_i in the message $X(n)$. This is set as follows:

$$P(m) = \{P(x_1), \ldots, P(x_i), \ldots, P(x_m)\}, \quad (5)$$

where m is the number of different elements in meaning x_i message $X(n)$, i.e. the power of the original message alphabet $X(n)$;

$P(x_i)$ is the probability of occurrence of elements x_i in the initial message $X(n)$, $i=\overline{1,m}$.

The next step is to take into account the correlations between the coded elements x_i. This stage is realized by quantities α and β in mathematical expression (6), the variability of which allows to implement the process of video image quality management.

The implementation of the stage of transformation of the alphabet of encoded data includes the following components:

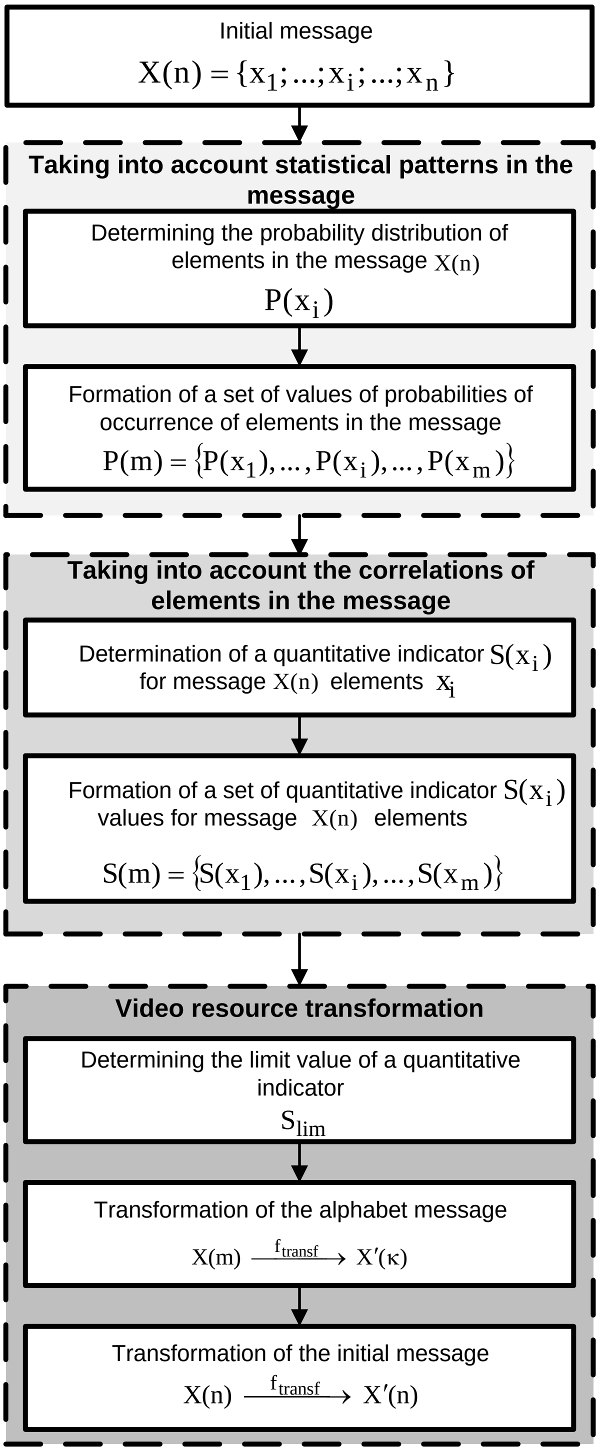

Fig. 1. Structural and functional scheme of transformation of coded video image by quantitative indicator

1. Determine the significance indicator $S(x_i)$ for items x_i initial message $X(n)$;

2. Formationset of values of the quantitative indicator $S(x_i)$ forelements x_i message $X(n)$. This is set as follows:

$$S(m) = \{S(x_1), \ldots, S(x_i), \ldots, S(x_m)\}, \quad (6)$$

where $S(m)$ is setvalues of the quantitative indicator $S(x_i)$ forelements x_i message $X(n)$.

3. Definition the limit value of the quantitative indicator $S(x_i)$ as a toolfor further transformation of the initial message alphabet. At this stage, the quality control of the reconstructed video image (size control) is implementedstandard deviation MSE) in accordance with the bandwidth of data transmission channels.

4. Video image alphabet transformation. This is given by the following expression:

$$X(m) \xrightarrow{f_{transf}} X'(\kappa), \quad (7)$$

where $X(m)$ is alphabet of the initial message $X(n)$;

$X'(\kappa)$ is transformed on a quantitative basis $S(x_i)$ message alphabet;

$f_{transf}(|X'(\kappa)|, S_{lim})$ is functionality of the initial message $X(n)$;

S_{lim} is threshold valuethe value of the quantitative indicator $S(x_i)$;

$|X'(\kappa)|$ is power of the transformed alphabet;

κ is the number of elements in the transformed alphabet $X'(\kappa)$ (power of the transformed alphabet).

Thus, in the process of forming the transformed alphabet of coded data by taking into account the quantitative indicator $S(x_i)$ significance regulates the power of the transformed alphabet.

In turn, the process of transforming the alphabet of encoded data is as follows:

- if the indicator of significance $S(x_i)$ element x_i message $X(n)$ less than the limit value S_{lim}, i.e. the following condition is met:

$$S(x_i) < S_{lim}, \quad (8)$$

then in the process of transformation he does not participate in the formation of a new alphabet, i.e.:

$$x_i \notin X'(\kappa). \quad (9)$$

- respectively, if the indicator of significance $S(x_i)$ element x_i message $X(n)$ more than the limit value S_{lim}, ie the following condition is met:

$$S(x_i) \geq S_{lim}, \quad (10)$$

then in the process of transformation such elements form a new alphabet, i.e.:

$$x_i \notin X'(\kappa). \quad (11)$$

Accordingly, as a result transformation of the alphabet of coded data on a quantitative indicator $S(x_i)$ power changes (decreases) $|X(m)|$ alphabet $X(m)$ coded data, i.e. the following expression will be valid:

$$|X'(\kappa)| < |X(m)|. \quad (12)$$

The next step is to transform the original message $X(n)$ taking into account the formed on the quantitative indicator of significance $S(x_i)$ transformed alphabet $X'(\kappa)$.

Transformation of the initial message $X(n)$ by quantitative significance $S(x_i)$ is given by the following expression:

$$X(n) \xrightarrow{f_{transf}} X'(n), \quad (13)$$

where $X'(n)$ is transformed by quantitative indicators $S(x_i)$ message.

The process of transforming the original message $X(n)$ quantitatively $S(x_i)$ implemented as follows:

- if the indicator of significance $S(x_i)$ element x_i initial message $X(n)$ more than the limit value S_{lim}, i.e. the condition specified by expression (12) is fulfilled, then in the process of transformation such elements form a new message, i.e.:

$$x_i \notin X'(n). \quad (14)$$

- respectively, if the indicator of significance $S(x_i)$ message element $X(n)$ less than the limit value S_{lim}, i.e. the condition given by expression (10) is fulfilled, then the element x_i is replaced by such an element x_δ belonging to the original message $X(n)$ for which the following condition is met:

$$\text{if } S(x_i) < S_{lim}, \text{ then } x_i \to x_\delta, \quad (15)$$

provided that $S(x_\delta) > S_{lim}$, $\gamma = \min(\gamma = |x_\delta - x_i|)$.

Thus, the process of transforming the original message $X(n)$ by quantitative significance $S(x_i)$ taking into account formulas (14), (15) will be set the following expression:

$$x'_i = \begin{cases} x_i, S(x_i) \geq S_{lim}; \\ x_\delta, S(x_i) < S_{lim}. \end{cases} \quad (16)$$

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Next, it is proposed to investigate the effectiveness of the developed method of video image transformation using the proposed quantitative indicator $S(x_i)$ from the standpoint of ensuring compliance with the above requirements (compactness of coded data in terms of ensuring the required high level of quality).

To this end, it is proposed to determine the optimal values α and β, which will ensure the adequacy of the proposed mathematical model for calculating the quantitative indicator of significance $S(x_i)$ message element $X(n)$.

3. Development of a mathematical model for the formation of a quantitative indicator of the significance of the elements of the initial message for the method of video image transformation

To develop an adequate mathematical model for the formation of a quantitative indicator of significance $S(x_i)$ elements x_i initial message $X(n)$ it is necessary to ensure compliance with a number of requirements:

- the developed mathematical model should provide the required level of quality of the transformed message;
- the transformation of the message in quantitative terms should have a significant impact on the probabilistic and statistical patterns, i.e. should provide a more favorable presentation of coded data;
- mathematical model of quantitative indicator formation $S(x_i)$ should not significantly complicate the process of algorithmic implementation of the method of transformation of the original message $X(n)$.

To determine the optimal values α and β (expression (4)) from the standpoint of ensuring the requirements for the required (high) level of video quality in terms of their compact representation and algorithmic complexity of the developed transformation method, a number of experimental studies were conducted using the developed software, listed in Figures 2, 3.

Halftone images (100 halftone images) of different degrees of saturation were used as initial data for experimental studies, typical examples of which are shown in Figures 4-6.

In turn, the results of experimental studies to determine the optimal from the standpoint of the above requirements of the values of indicators α and β shown in Fig.7-9.

Analysis of the results shown in Fig.7 shows that the optimal value of the indicator α is the following

```
void countSignificance(){
    int hlc = 4;
    proCS = new float[proCC.length];
    for(int i=0; i<proCC.length; i++){
      if(proCC[i]==0)proCS[i]=0;
      else{
        float sum = 1;
        int ch0 = (int)red(i);
        int ch1 = (int)green(i);
        int ch2 = (int)blue(i);
        for(int p0=hlc+ch0; p0<hlc+ch0;p0++){
          for(int p1=hlc+ch1;
p1<hlc+ch1;p1++){
            for(int p2=hlc+ch2;
p2<hlc+ch2;p2++){
              if(p0>=0 & p0<=256 & p1>=0 &
p1<=256 & p2>=0 & p2<=256){
                int p = mycolorC(p2,p1,p0);
                if(p!=i | proCC[p]!=0){
                  sum+=proCC[p]/pow(cDist(i,pk
),p);
                }
              }
            }
          }
        }
        proCS[i]=proCC[i]/sum;
```

Fig. 2. Listing of software that implements the calculation of the significance of the elements of the message

```
void filtColors(){
    for(int x=0; x<fxs; x++){
      for(int y=0; y<fys; y++){
        int ch0 = (int)masCH0[x][y];
        int ch1 = (int)masCH1[x][y];
        int ch2 = (int)masCH2[x][y];
        int i = mycolorC(ch0,ch1,ch2);
        if(proCS[i]<=sgbd){
          if(dis)i = mycol-
orC((int)(masCH0[x][y]+random(disK*2)-
disK),(int)(masCH1[x][y]+random(disK*2)-
disK),(int)(masCH2[x][y]+random(disK*2)-
disK));
          int nc = findNearestSig(i);
          masCH0[x][y] = (red(nc));
          masCH1[x][y] = (green(nc));
          masCH2[x][y] = (blue(nc));
```

Fig. 3. Listing of software that implements the transformation of the alphabet of the message

value: $\alpha = 8$. This is due to the fact that this value corresponds to the minimum standard deviation MSE i.e.:

$$MSE = MSE_{min}.$$

A further increase in the value of the indicator is answered α does not change the standard deviation MSE that is, if $\alpha \geq 8$, then $MSE \approx const$ and is equal to:

$$MSE \approx 0{,}63\%. \qquad (17)$$

Fig. 4. Example of a weakly saturated image, airplane.bmp (512x512)

Fig. 5. Example of medium saturated image, tank.bmp (512x512)

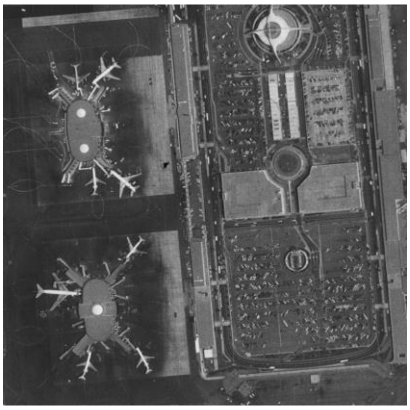

Fig. 6. Example of a highly saturated image, airport.bmp (512x512)

Accordingly, the decrease in the value of the indicator α leads to an increase in standard deviation MSE. Yes if $\alpha = 4$, then the standard deviation MSE will have the following meaning:

$$MSE \approx 0{,}9\% .$$

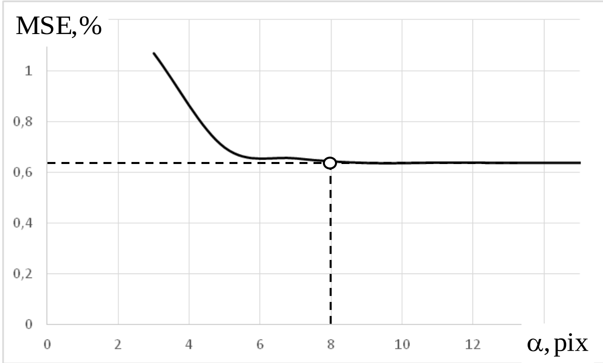

Fig. 7. Diagram of the dependence of the standard deviation MSE from the value of the indicator α, which takes into account the correlations between the elements of the message

In turn, in Fig. 8 shows an estimate of the dependence of the complexity of the algorithmic implementation of the proposed quantitative indicator on the value α.

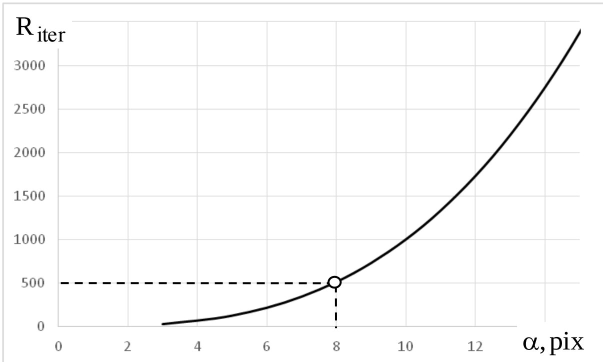

Fig. 8. Diagram of the dependence of the average number of iterations R_{iter} from the value of the indicator α

Analysis of the results shown in Fig. 6 indicates that the increase in the value of the indicator α leads to a significant increase in the average number of iterations R_{iter} required to implement the proposed approach to quantify $S(x_i)$ in order to further transform the data of the information resource.

So for the case when $\alpha = 8$, i.e. has the optimal value from the standpoint of ensuring the required level of quality (the result of previous experimental studies shown in Fig.6), the average number of iterations R_{iter} will have the following meaning:

$$R_{iter} = 500. \qquad (18)$$

Accordingly, a slight increase in the indicator α leads to a significant increase in the complexity of the algorithmic implementation, i.e. the following condition is met:

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$$\text{If } \alpha_1 > \alpha_2, \text{ then } R_{iter_1} >> R_{iter_2}.$$

So when $\alpha = 10$ average number of iterations R_{iter} is equal to 1000, i.e.:

$$R_{iter} = 1000.$$

In turn, a comprehensive assessment of the dependence of the standard deviation MSE from the value of indicators α and β shown in fig. 9.

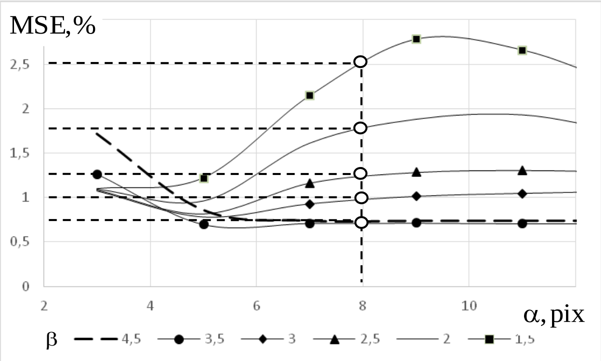

Fig. 9. Diagram of the dependence of the standard deviation MSE from the value of indicators α and β

The results of experimental studies shown in Fig. 9, indicate that for the developed mathematical model of the formation of a quantitative indicator $S(x_i)$ the following values of indicators are adequate from the point of view of ensuring the requirements for ensuring the required level of video image quality α and β:

$$\alpha = 8, \ \beta = 3{,}5. \tag{19}$$

Taking into account the results of experimental research described by expression (19), a mathematical description of the quantitative indicator of significance $S(x_i)$ elements x_i initial message $X(n)$ will look like this:

$$S(x_i) = \frac{P(x_i)}{\sum_{j=1}^{8} \frac{P(x_j)}{D(x_i, x_j)^{3,5}}}, \tag{20}$$

Thus, as a result of the conducted experimental researches the mathematical model of formation of a quantitative indicator of significance was formed $S(x_i)$ elements x_i initial message $X(n)$ that ensures compliance with the following requirements:

- provides the required (high) level of quality of the transformed message, i.e. $MSE \to 0$;
- differs in simplicity of algorithmic implementation.

Next, to determine the compression characteristics of the transformed message $X'(n)$ on the proposed quantitative basis $S(x_i)$ it is proposed to evaluate the probabilistic and statistical characteristics of the transformed alphabet $X'(\kappa)$ message $X'(n)$.

4. Evaluation of the effectiveness of the developed method of transformation of the initial message by a quantitative indicator

To evaluate the effectiveness of the developed method of transformation of the initial message $X(n)$ quantitatively $S(x_i)$ from the standpoint of a more favorable presentation of coded data, a number of experimental studies were conducted using the developed software product. As limit values S_{lim} quantitative indicator $S(x_i)$ the following were used:

- for weakly saturated images the limit value S_{lim} equal to:

$$S_{lim\,wsi} \approx 20{,}68, \tag{21}$$

where $S_{lim\,wsi}$ – threshold valuethe value of a quantitative indicator of significance $S(x_i)$ element x_i initial message $X(n)$ for low-saturated video images;

- for medium-saturated images:

$$S_{lim\,msi} \approx 4{,}61, \tag{22}$$

where $S_{lim\,msi}$ is threshold valuequantitative significance indicator $S(x_i)$ element x_i initial message $X(n)$ for medium-saturated video images;

- for highly saturated images:

$$S_{lim\,hsi} \approx 3{,}13, \tag{23}$$

where $S_{lim\,hsi}$ is threshold valuequantitative significance indicator $S(x_i)$ element x_i initial message $X(n)$ for highly saturated video images.

Evaluation of the results of the transformation of coded data by quantitative indicators $S(x_i)$ from the standpoint of capacity change $|X(m)|$ alphabets $X(m)$ initial messages $X(n)$ for conditions where the limit value S_{lim} takes the values given in expressions (21) - (23), presented in Fig. 10.

Figure 10 adopted the following notation:

- IA – power $|X(m)|$ alphabet $X(m)$ initial message $X(n)$;

- TA – power $|X'(\kappa)|$ alphabet $X'(\kappa)$ transformed message $X'(n)$.

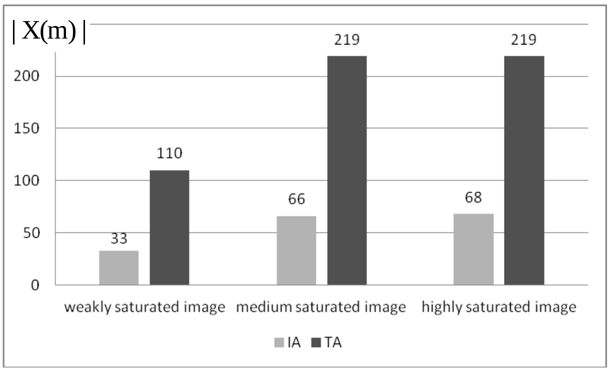

Fig. 10. Diagram for estimating the change in the power of encoded data using the developed method of transformation of different degrees of saturation of video images

Analysis of the results shown in Fig. 10 shows that the use of the method of transformation of the initial message $X(n)$ quantitatively $S(x_i)$ allows:

- reduce power $|X(m)|$ alphabet $X(m)$ encoded data from 3,22 times - for highly saturated to 3,33 times - for weakly saturated video images;

- reduce power $|X(m)|$ alphabet $X(m)$ coded data by an average of 70%.

Next, in order to evaluate the effectiveness of the proposed method of transformation of the initial message $X(n)$ by quantitative assessment $S(x_i)$ from the standpoint of providing a more favorable presentation of coded data, it is proposed to assess the impact of the transformation of the alphabet $X(m)$ on probabilistic and statistical regularities in the transformed message $X'(n)$. To this end, a number of experimental studies were performed, the results of which are shown in Fig.11 - 13.

The probabilistic distribution of elements in the initial and transformed message for low-saturated video images is presented in Fig. 11.

In fig. 11 the following designations are accepted:

- blue dots are elements x_i alphabet $X(m)$ initial message $X(n)$;

- red dots – elements x_i' alphabet $X'(\kappa)$ transformed message $X'(n)$.

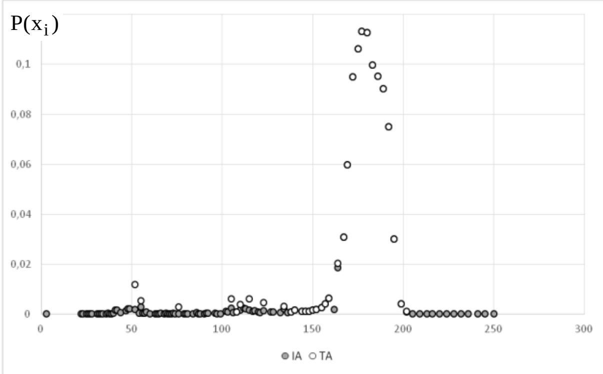

Fig. 11. Diagram of probability distribution of elements in the initial and transformed message for low-saturated video images

Analysis of the results of the alphabet transformation $X(m)$ initial message $X(n)$ for low-saturation video images in quantitative terms $S(x_i)$ from the standpoint of estimating the dynamics of the probability distribution of elements indicates that the proposed method of transformation allows (Fig. 11):

- increase the dynamic range of values of the probabilities of occurrence of elements in the message by an average of 20%. So for the transformed message $X'(n)$ the minimum value of the probability of occurrence of the element x_i' consists of:

$$P_{min}(x_i') = 0{,}004 .$$

In turn, the minimum value of the probability of occurrence of the element x_i in the initial message $X(n)$ has the following meaning:

$$P_{min}(x_i) = 0{,}0000038.$$

This means that the proposed method of transforming the original message $X(n)$ allows you to significantly increase the minimum probability of the element in the transformed message $X'(n)$, ie the following condition will be met:

$$P_{min}(x_i') >> P_{min}(x_i) ;$$

- ensure the creation of more favorable conditions for further encoding of the data of the video information resource in comparison with the initial message.

Dynamics of probability distribution of elements after using the developed method of transformation of the initial message $X(n)$ for medium-saturated video images is shown in Fig. 12.

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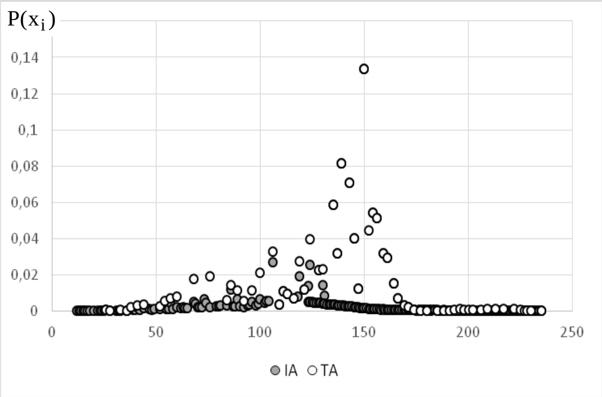

Fig. 12. Diagram of probability distribution of elements in the initial and transformed message for medium-saturated video images

Analyzing the results of the transformation of the alphabet $X(m)$ initial message $X(n)$ for medium-saturated video images from the standpoint of the dynamics of the probability distribution of elements x_i (Fig. 12), we can draw the following conclusions:

- for the initial $X(n)$ and transformed message $X'(n)$ the maximum value of the probability of occurrence of the element is 0,13, i.e.:

$$P_{max}(x_i) = P_{max}(x_i') = 0{,}13;$$

- however, the minimum value of the probability of occurrence of the element x_i' in the transformed message $X'(n)$ 11 times the same value for the original message:

$$P_{min}(x_i) = 0{,}000004; P_{min}(x_i') = 0{,}000042;$$

- alphabet transformation $X(m)$ initial message $X(n)$ by quantitative significance $S(x_i)$ allows you to significantly increase the dynamic range of values of the probability distribution of elements x' transformed message $X'(n)$, i.e. the following condition is met:

$$P(x_i') \geq P(x_i).$$

So for the initial message $X(n)$ weighted average probability value $P(x_i)$ the appearance of the element is 0,044, i.e.:

$$P_{c3}(x_i) \approx 0{,}044.$$

In turn, the weighted average probability value $P(x_i')$ the appearance of the element x' in the transformed message $X'(n)$ is 0,052, i.e.:

$$P_{c3}(x_i') \approx 0{,}052.$$

Thus, for medium-saturated video images, the transformation of the alphabet $X(m)$ initial message $X(n)$ allows to increase the dynamic range of values of the probability distribution of elements by an average of 18 %.

Influence of using the developed method of transformation of the initial message $X(n)$ on a quantitative basis $S(x_i)$ on the probabilistic distribution of elements in the transformed message $X'(n)$ for highly saturated video images is shown in Fig. 13.

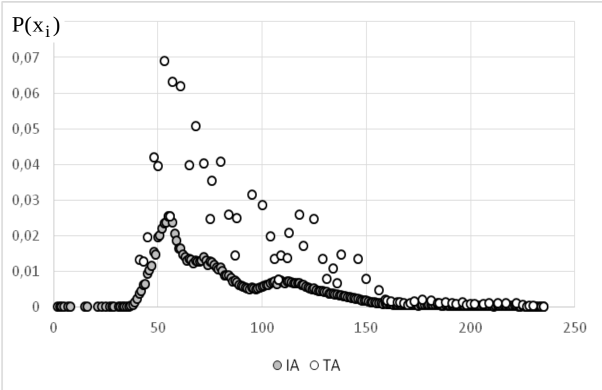

Fig. 13. Diagram of probability distribution of elements in the initial and transformed message for highly saturated video images

Analyzing the results of the transformation of the initial message $X(n)$ (highly saturated video images) in quantitative terms $S(x_i)$ significance of the elements shown in Fig. 13, we can draw the following conclusions:

- alphabet transformation $X(m)$ initial message $X(n)$ allows you to significantly change the dynamic range of values of the probabilities of occurrence of elements in the transformed message $X'(n)$.

This is the maximum value of the probability of the element appearing in the transformed message $X'(n)$ increases almost 2,7 times:

$$P_{max}(x_i) \approx 0{,}025, P_{max}(x_i') \approx 0{,}069, \frac{P_{max}(x_i')}{P_{max}(x_i)} \approx 2{,}7.$$

Accordingly, the minimum value of the probability of occurrence of the element x_i' in the transformed message $X'(n)$ increases approximately 20 times:

$$P_{min}(x_i) \approx 0,0000763, \ P_{min}(x_i') \approx 0,0000038,$$
$$\frac{P_{min}(x_i')}{P_{min}(x_i)} \approx 20;$$

- for highly saturated video images, alphabet transformation $X(m)$ initial message $X(n)$ allows to increase the dynamic range of values of the probability distribution of elements on average by almost 3 times.

The method of alphabet transformation is developed $X(m)$ initial message $X(n)$ due to the proposed quantitative feature $S(x_i)$ significance of the elements x_i allows to carry out process of quality management of the transformed message $X'(n)$. So the growth of the threshold S_{lim} quantitative indicator $S(x_i)$ the importance of the elements of the alphabet $X(m)$ initial message $X(n)$ leads to a reduction in power $|X'(\kappa)|$ alphabet $X'(\kappa)$ transformed message $X'(n)$ i.e.:

$$\text{if } S_{lim}(\kappa) > S_{lim}(\theta), \text{ then } |X'(\kappa)| < |X'(\theta)|, \quad (24)$$

where $S_{lim}(\kappa), S_{lim}(\theta)$ is limit values quantitative indicator $S(x_i)$ significance κ - th and θ - th elements of the original message $X(n)$;

$|X'(\theta)|$ is power of the alphabet $X'(\theta)$, transformed by the threshold value $S_{lim}(\theta)$ quantitative indicator $S(x_i)$.

This, in turn, allows you to increase the probability values $P(x_i')$ the appearance of elements in the transformed message $X'(n)$, i.e. the following condition will be met:

$$P(x'_\kappa, S_{lim}(\kappa)) > P(x'_\theta, S_{lim}(\theta)), \quad (25)$$

where $P(x'_\kappa, S_{lim}(\kappa))$ is the minimum value of the probability of occurrence of an element of the transformed alphabet $X'(\kappa)$ in terms of using the threshold value of the indicator $S_{lim}(\kappa)$;

$P(x'_\theta, S_{lim}(\theta))$ is the minimum value of the probability of occurrence of an element of the transformed alphabet $X'(\theta)$ in terms of using the threshold value of the indicator $S_{lim}(\theta)$.

However, it should be noted that the growth of the threshold value S_{lim} quantitative indicator $S(x_i)$ along with the positive dynamics of the probability distribution of elements in the transformed message $X'(n)$ leads to a controlled deterioration in the quality of video images (increasing the standard deviation MSE), i.e.:

$$\text{if } S_{lim}(\kappa) > S_{lim}(\theta),$$
$$\text{then } MSE(X'(\theta)) < MSE(X'(\kappa)), \quad (26)$$

where $MSE(X'(\theta))$ is standard deviation for the transformed message with the alphabet $X'(\theta)$;

$MSE(X'(\theta))$ is standard deviation for the transformed message with the alphabet $X'(\kappa)$.

Thus, the analysis of the results of estimating the dynamics of the probability distribution of elements in the transformed message $X'(n)$ for different degrees of saturation of video image classes indicates that the developed method of message transformation $X(n)$ quantitatively $S(x_i)$ significance of the elements x_i initial message $X(n)$ allows you to provide a more favorable representation of encoded data with the ability to control the quality of the original video images.

Therefore, it is further proposed to develop a method of encoding the data of the video information resource using the proposed approach in order to ensure a compact representation of the encoded data in a given (high) quality video images.

Conclusions

1. In the conditions of use of dynamic video surveillance systems one of the main problem factors is the limitation of the bandwidth of wireless data transmission technologies. In this regard, the growing requirements for video information resource from the standpoint of ensuring the required level of reliability of video images in terms of their compact presentation.

2. To date, in order to meet these requirements are actively used compression technologies based on the conceptual basis of algorithms of the JPEG family. However, they have a number of significant disadvantages. The main ones are: the complexity of algorithmic implementation, the imbalance between compression and quality characteristics, which in some cases can lead to the loss of key (small) elements that have semantic significance in the decision-making process to respond to crisis situations.

Therefore, the use of these technologies does not provide the required high level of video quality in terms of their compact presentation.

Therefore, to solve the scientific and applied problem of ensuring the appropriate level of reliability of video information in terms of its compact presentation, a fundamentally new approach is proposed - the transformation of the alphabet of encoded video

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data on a quantitative basis. To this end, a mathematical model of quantitative trait formation was developed, which determines the significance of the elements of the initial message by taking into account correlations and probabilistic and statistical characteristics.

3. The developed method of transformation of the alphabet of the initial message allows to create conditions for more favorable representation of the coded video data. This is due to the improvement of probabilistic and statistical patterns for the transformed message in terms of ensuring a high level of reliability ($MSE_{рм} \to 0$).

So the analysis of efficiency of results of the experimental researches received by use of the developed software product, testifies that use of the developed method allows:

- increase the dynamic range of values of the probabilities of occurrence of elements in the transformed message for low-saturated video images by an average of 20 %.

- for medium-saturated video images, alphabet transformation $X(m)$ initial message $X(n)$ allows to increase the dynamic range of values of the probability distribution of elements by an average of 18 %;

- for highly saturated video images to increase the dynamic range of values of the probability distribution of elements by an average of 3 times;

- create conditions for more favorable presentation of encoded video data.

4. Thus, for the first time a method of video data alphabet transformation was developed, which simultaneously takes into account the correlations between the elements of the original message and the probabilistic approach using the developed mathematical model of quantitative indicator formation.

Distinctive features of the developed method are that the transformation of the alphabet of the original message is carried out without significant loss of quality of the video information resource, i.e. $MSE_{рм} \to 0$ based on a quantitative feature - signs of the importance of the elements of the original message. This allows you to get the following results:

1) create conditions to reduce the structural redundancy of the code representation of the video resource by significantly increasing the dynamic range of values of the probabilities of occurrence of elements in the transformed message;

2) conditions are created to increase the efficiency of further use of statistical coding methods;

3) conditions are created to reduce the time for data processing, due to the fact that the developed method of transforming the alphabet of video images is simple algorithmic implementation and compared to existing does not involve the use of a number of processing steps (for example in JPEG family algorithms in another, orthogonal transformations, quantization, etc.).

Contribution of authors: review and analysis of information sources – **S. Khmelevsky, O. Khmelevskaya, O. Yakobinchuk**; development of conceptual provisions of the research – **M. Parkhomenko, O. Musienko**; formulation of the purpose and statement of the problem of researches – **S. Khmelevsky, I. Tupitsa**, **Ya. Borovensky**; development of mathematical models and analysis of research results – **M. Parkhomenko, I. Tupitsa, O. Musienko**; development of methods – **I. Tupitsa, O. Musienko, M. Parkhomenko**; selection and use of software and hardware for modeling and presentation of results – **Ya. Borovensky**, **O. Pershin, I. Nikora**; formulation of conclusions – **O. Pershin**. The research was performed within the framework of research work code "Intelligence". All authors have read and agreed with the published version of the manuscript.

References (GOST 7.1:2006)

1. Miano, J. Compressed image file formats: JPEG, PNG, GIF, XBM, BMP [Text] / by John Miano. – 1999. – 264 p.

2. Pratt, W. K. Slant transforms image coding [Text] / W. K. Pratt, W. H. Chen, L. R. Welch // Proc. Computer processing in communications. – 1969. – P. 63–84.

3. Wallace, G. K. The JPEG Still Picture Compression Standard [Text] / G. K. Wallace // Communication in ACM. – 1991. – Vol. 34, No. 4. – P. 31-34.

4. Wallace, G. K. Overview of the JPEG (ISO/CCITT) Still image compression: image processing algorithms and techniques [Text] / G. K. Wallace // Proc. of SPIE-IS&T Electronic Imaging (SPIE). – 1990. – Vol. 1244. – P. 220-233.

5. Utility Driven Adaptive Preprocessing for Screen Content Video Compression [Text] / S. Wang, X. Zhang, X. Liu, J. Zhang, S. Ma, W. Gao // IEEE Transactions on Multimedia. – 2017. – Vol. 19, No. 3. – P. 660–667.

6. Gonzales, R. C. Digital image processing. [Text] / R. C. Gonzales, R. E. Woods // Prentice Inc. Upper Saddle River. – 2002. –779 p.

7. Dong, W. JPEG Compression Forensics against Resizing [Text] / W. Dong, J. Wang // IEEE Trustcom/ BigDataSE/IвSPA. – 2016. – P. 1001 –1007. DOI: 10.1109/TrustCom.2016.0168.

8. Richter, T. Error Bounds for HDR Image Coding with JPEG XT [Text] / T. Richter // Data Compression Conference (DCC). – 2017. – P. 122–130. DOI: 10.1109/DCC.2017.7.

9. A Fast JPEG Image Compression Algorithm Based on DCT [Text] / W. Xiao, N. Wan, A. Hong, *X. Chen // IEEE International Conference on Smart Cloud (SmartCloud). – 2020. – P. 106–110. DOI: 10.1109/ SmartCloud49737. 2020.00028.*

10. Rippel, O. Learned Video Compression [Text] / O. Rippel // IEEE/CVF International Conference on Computer Vision (ICCV). – 2019. – P. 3453–3462. DOI: 10.1109/ICCV. 2019.00355.

11. Hierarchical model of a complex of IoT devices based on the use of a wireless sensor network [Text] / Y. Afanasiev, V. Afanasiev, V. Chystov, O. Sitkov, V. Surhai, S. Fediuk // Advanced Trends in Information Theory (ATIT'2020). – 2020. – P. 168–171. DOI: 10.1109/ ATIT50783.2020. 9349340.

12. Performance of H.264, H.265, VP8 and VP9 Compression Standards for High Resolutions [Text] / J. Bienik, M. Uhrina, M. Kuba, M. Vaculik // 19th International Conference on Network-Based Information Systems (NBiS). – 2016. – P. 246-252. DOI: 10.1109/NBiS. 2016.70.

13. Cruise UAV Video Compression Based on Long-Term Wide-Range Background [Text] / X. Wang, J. Xiao, R. Hu, Z. Wang // Data Compression Conference (DCC). – 2017. – P. 466-467. DOI: 10.1109/DCC. 2017.71.

14. Minallah, N. Performance Analysis of H.265/ HEVC (High-Efficiency Video Coding) with Reference to Other Codecs [Text] / N. Minallah, S. Gul, M. Bokhari // 13th International Conference on Frontiers of Information Technology (FIT). – 2015. – P. 216–221. DOI: 10.1109/ FIT.2015.46.

15. Research of access control system using wireless sensor network [Text] / Y. Afanasiev, V. Afanasiev, V. Chystov, O. Sitkov, V. Surhai, S. Fediuk // IEEE Problems of Infocommunications. Science and Technology (PICS&T). – 2020. – P. 663–668. DOI: 10.1109/PICST51311.2020.9468102.

16. Analysis of opportunities to improve image denoising efficiency for dct-based filter [Text] / O. N. Zemliachenko, I. G. Ivakhnenko, G. A. Chernova, V. V. Lukin // Radioelectronic and Computer Systems. – 2018. – No. 2(86). – P. 4-12. DOI: 10.32620/reks.2018.2.01.

17. Methodology for restructuring information resource data to improve the efficiency of statistical coding [Text] / I. Tupitsya // Science-based technologies. – 2019. – Vol. 42, No. 2. – P. 262 – 269. DOI: 10.18372/ 2310-5461.42.13801.

18. Neural Inter-Frame Compression for Video Coding [Text] / A. Djelouah, J. Campos, S. Schaub-Meyer, C. Schroers // IEEE/CVF International Conference on Computer Vision (ICCV). – 2019. – P. 6420–6428. DOI: 10.1109/ICCV.2019. 00652.

19. Narmatha, C. A LS-compression scheme for grayscale images using pixel based technique [Text] / C. Narmatha, P. Manimegalai, S. Manimurugan // International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT). – 2017. – P. 1–5. DOI: 10.1109/IGEHT.2017.8093980.

20. Alam, M. A. Faster Image Compression Technique Based on LZW Algorithm Using GPU Parallel Processing [Text] / M. A. Alam // Joint 7th International Conference on Informatics, Electronics & Vision (ICIEV) and 2nd International Conference on Imaging, Vision & Pattern Recognition (icIVPR). – 2018. – P. 272–275. DOI: 10.1109/ICIEV.2018.8640956.

21. Comparative analysis of lossless compression techniques in efficient DCT-based image compression system based on Laplacian Transparent Composite Model and An Innovative Lossless Compression Method for Discrete-Color Images [Text] / T. Poolakkachalil, S. Chandran, R. Muralidharan, K. Vijayalakshmi // 3rd MEC International Conference on Big Data and Smart City (ICBDSC). – 2016. – P. 1–6. DOI: 10.1109/ ICBDSC.2016.7460360.

22. The Method of Crypto-Semantic Presentation of Images Based on the Floating Scheme in the Basis of the Upper Boundaries [Text] / V. Barannik, I. Tupitsya, S. Sidchenko, R. Tarnopolov // IEEE Problems of Infocommunications. Science and Technology (PICS&T). – 2015. – P. 248–251. DOI: 10.1109/INFOCOMMST.2015.7357326.

23. Joint Learned and Traditional Video Compression for P Frame [Text] / Z. Wang, R. Liao, Y. Ye // IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW). – 2020. – P. 560–564. DOI: 10.1109/CVPRW50498.2020.00075.

24. Comparison of lossless video and image compression codecs for medical computed tomography datasets [Text] / V. Bui, L. Chang, D. Li, L. Hsu, M. Chen // IEEE International Conference on Big Data (Big Data). – 2016. – P. 3960-3962. DOI: 10.1109/BigData. 2016.7841075.

25. Learned Variable-Rate Image Compression with Residual Divisive Normalization [Text] / M. Akbari, J. Liang, J. Han, C. Tu // IEEE International Conference on Multimedia and Expo (ICME). – 2020. – P. 1–6. DOI: 10.1109/ICME46284.2020.9102877.

26. Shinde, T. Efficient Image Set Compression. [Text] / T. Shinde // IEEE International Conference on Image Processing (ICIP). – 2019. – P. 3016-3017. DOI: 10.1109/ICIP. 2019.8803230.

27. M-LVC: Multiple Frames Prediction for Learned Video Compression [Text] / J. Lin, D. Liu, H. Li, F. Wu // IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). – 2020. – P. 3543–3551. DOI: 10.1109/CVPR42600. 2020.00360.

28. The application for internal restructuring the data in the entropy coding process to enhance the information resource security [Text] / V. Barannik, S. Sidchenko, I. Tupitsya, S. Stasev // IEEE East-West Design and Test Symposium (EWDTS). – 2016. – P. 1–4. DOI: 10.1109/ EWDTS.2016.7807749.

29. Artuğer, F. Fractal Image Compression Method for Lossy Data Compression [Text] / F. Artuğer, F. Özkaynak // International Conference on Artificial Intelligence and Data Processing (IDAP). – 2018. – P. 1–6. DOI: 10.1109/IDAP. 2018.8620735.

30. Iris image compression using wavelets transform coding [Text] / P. Arnob, Z. Tanvir, P. Prajoy, A. Rafi, M. Muktadir Rahman, Kh. Mamdudul Haque // 2nd International Conference on Signal Processing and

ISSN 1814-4225 (print)
ISSN 2663-2012 (online)

Integrated Networks (SPIN). – 2015. – P. 544–548. DOI: 10.1109/SPIN.2015.7095407.

31. Morphological component decomposition combined with compressed sensing for image compression [Text] / X. Zhu, L. Liu, Na Jin, P. Ai // IEEE International Conference on Information and Automation (ICIA), DOI: 10.1109/ICInfA.2016.7832096.

32. Encode when necessary: Correlated network coding under unreliable wireless links [Text] / S. Wang, M. Kim, Z. Yin, T. He // ACM Transactions on Sensor Networks. – 2017. – Vol. 13, No. 1. DOI: 10.1145/3023953.

33. The Application of the Internal Restructuring Method of the Information Resource Data According to the Sign of the Number of Series of Units to Improve the Statistical Coding Efficiency [Text] / V. Barannik, I. Tupitsya, V. Barannik, S. Shulgin, A. Musienko, R. Kochan, O. Veselska // 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS). – 2019. – P. 65-69. DOI: 10.1109/IDAACS.2019.8924460.

34. Phatak, A. A Non-format Compliant Scalable RSA-based JPEG Encryption Algorithm [Text] / A. Phatak // International Journal of Image, Graphics and Signal Processing. – 2016. – Vol. 8, No. 6. – P. 64–71. DOI: 10.5815/ijigsp.2016.06.08.

35. Lossless Compression of JPEG Coded Photo Collections [Text] / H. Wu, X. Sun, J. Yang, W. Zeng, F. Wu // IEEE Transactions on Image Processing. – 2016. – Vol. 25. – No. 6. – P. 2684–2696. DOI: 10.1109/TIP. 2016.2551366.

36. Lee, J. Context-adaptive entropy model for end-to-end optimized image compression [Text] / J. Lee, S. Cho, S.-K. Beack. – 2018. Arxiv: 1809.10452.

37. Chen, C. A research on anti-jamming method based on compressive sensing for OFDM analogous system [Text] / C. Chen, Y. Zhuo // 17th International Conference on Communication Technology (ICCT). – 2017. – P. 655–659. DOI:10.1109/ICCT.2017.8359718.

38. Encode when necessary: Correlated network coding under unreliable wireless links [Text] / S. Wang, S. Kim, Z. Yin, T. He // ACM Transactions on Sensor Networks. – 2017. – Vol. 13, No.1. – P. 24 – 29. DOI: 10.1145/ 3023953.

39. Deep compression: Compressing deep neural networks with pruning, trained quantization and huffman coding [Text] / S. Han, H. Mao, W. Dally. – 2015. arXiv: 1510.00149.

40. Increasing the efficiency of information transmission in communication channels [Text] / B. Zhurakovskyi, J. Boiko, V. Druzhynin, I. Zeniv, O. Eromenko // Indonesian Journal of Electrical Engineering and Computer Science. – 2020. – Vol. 19, No. 3. – P. 1306-1315. DOI: 10.11591/ijeecs.v19.i3.

41. The Method of Clustering Information Resource Data on the Sign of the Number of Series of Units as a Tool to improve the Statistical Coding Efficiency [Text] / V. Barannik, I. Tupitsya, O. Dodukh, V. Barannik, M. Parkhomenko // IEEE 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM). – 2019. – P. 32–35. DOI: 10.1109/CADSM.2019.8779243.

42. Two-Hierarchical Scheme of Statistical Coding of Information Resource Data with Quantitative Clustering [Text] / V. Barannik, I. Tupitsya, I. Gurzhii, V. Barannik, S. Sidchenko, O. Kulitsa // IEEE International Conference on Advanced Trends in Information Theory (ATIT). – 2019. – P. 89–92. DOI: 10.1109/ ATIT49449.2019.9030451.

43. The analysis of the internal restructuring method efficiency used for a more compact representation of the encoded data [Text] / V. Barannik, I. Tupitsya, O. Kovalenko, Y. Sidchenko, V. Yroshenko, O. Stepanko // Advanced Trends in Information Theory (ATIT'2020). – 2020. – P. 89–92. DOI: 10.1109/ ATIT50783.2020.9349307.

44. Development of the external restructuring method to increase the efficiency of information resource data encoding [Text] / S. Khmelevskiy, I. Tupitsya, Q. A. Mahdi, O. Musienko, M. Parkhomenko, Y. Borovensky // Information Processing Systems. – 2021. – Vo. 3, No. 166. – P. 52-61. DOI: 10.30748/soi.2021. 166.06.

References (BSI)

1. Miano, J. *Compressed image file formats: JPEG, PNG, GIF, XBM, BMP*. 1999. 264 p.

2. Pratt, W. K., Chen, W. H., Welch L. R. Slant transforms image coding. *Proc. Computer Processing in communications*, 1969, pp. 63-84.

3. Wallace, G. K. The JPEG Still Picture Compression Standard. *Communication in ACM*, 1991, vol. 34, no. 4, pp. 31-34.

4. Wallace, G. K. Overview of the JPEG (ISO/CCITT) Still image compression: image processing algorithms and techniques. *Proc. of SPIE-IS&T Electronic Imaging (SPIE)*, 1990, vol. 1244, pp. 220-233.

5. Wang, S., Zhang, X., Liu, X., Zhang, J., Ma, S., Gao, W. Utility Driven Adaptive Preprocessing for Screen Content Video Compression. *IEEE Transactions on Multimedia*, 2017, vol. 19, no. 3, pp. 660-667.

6. Gonzales, R. C., Woods, R. E. Digital image processing. *Prentice Inc. Upper Saddle River*, 2002. 779 p.

7. Dong, W., Wang, J. JPEG Compression Forensics against Resizing. *IEEE Trustcom/ BigDataSE/I6SPA*, Tianjin, China, 2016, pp. 1001-1007. DOI: 10.1109/TrustCom.2016.0168.

8. Richter, T. Error Bounds for HDR Image Coding with JPEG XT. *Data Compression Conference (DCC)*, 2017, pp. 122-130. DOI: 10.1109/DCC.2017.7.

9. Xiao, W., Wan, N.A., Hong and Chen, X. A Fast JPEG Image Compression Algorithm Based on DCT. *IEEE International Conference on Smart Cloud (SmartCloud)*, 2020, pp. 106-110. DOI: 10.1109/ SmartCloud49737. 2020.00028.

10. Rippel, O. Learned Video Compression. *IEEE/CVF International Conference on Computer Vision (ICCV)*, 2019, pp. 3453-3462. DOI: 10.1109/ICCV. 2019.00355.

11. Afanasiev, Y., Afanasiev, V., Chystov, V., Sitkov, O., Surhai, V., Fediuk, S. Hierarchical model of a complex of IoT devices based on the use of a wireless sensor network. *IEEE International Conference on Advanced Trends in Information Theory (ATIT)*, 2020, pp. 168-171. DOI: 10.1109/ATIT50783.2020.9349340.

12. Bienik, J., Uhrina, M., Kuba, M. and Vaculik, M. Performance of H.264, H.265, VP8 and VP9 Compression Standards for High Resolutions. *19th International Conference on Network-Based Information Systems (NBiS)*, 2016, pp. 246-252. DOI: 10.1109/NBiS. 2016.70.

13. Wang, X., Xiao, J., Hu, R., Wang, Z. Cruise UAV Video Compression Based on Long-Term Wide-Range Background. *Data Compression Conference (DCC)*, 2017, pp. 466-467. DOI: 10.1109/DCC.2017.71.

14. Minallah, N., Gul, S., Bokhari, M. Performance Analysis of H.265/HEVC (High-Efficiency Video Coding) with Reference to Other Codecs. *13th International Conference on Frontiers of Information Technology (FIT)*, 2015, pp. 216-221. DOI: 10.1109/ FIT.2015.46.

15. Afanasiev, Y., Afanasiev, V., Chystov, V., Sitkov, O., Surhai, V., Fediuk, S. Research of access control system using wireless sensor network. *IEEE Problems of Infocommunications. Science and Technology (PICS&T): proceedings of International Scientific-Practical Conference*, 2020, pp. 663-668. DOI: 10.1109/PICST51311.2020.9468102.

16. Zemliachenko, O. N., Ivakhnenko, I. G., Chernova, G. A., Lukin, V. V. Analysis of opportunities to improve image denoising efficiency for dct-based filter. *Radioelektronni i komp'uterni sistemi – Radioelectronic and computer systems*, 2018, no. 2(86), pp. 4-12. DOI: 10.32620/reks.2018.2.01.

17. Tupitsya, I. Methodology for restructuring information resource data to improve the efficiency of statistical coding. *Science-based technologies*. vol. 42, no. 2 (2019), pp. 262–269. DOI: 10.18372/2310-5461.42.13801.

18. Djelouah, A., Campos, J., Schaub-Meyer, S., Schroers, C. Neural Inter-Frame Compression for Video Coding. *IEEE/CVF International Conference on Computer Vision (ICCV)*, 2019, pp. 6420-6428. DOI: 10.1109/ICCV.2019. 00652.

19. Narmatha, C., Manimegalai, P., Manimurugan, S. A LS-compression scheme for grayscale images using pixel based technique. *International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT)*, 2017, pp. 1-5, DOI: 10.1109/ IGEHT.2017.8093980.

20. Alam, M. A., Faster Image Compression Technique Based on LZW Algorithm Using GPU Parallel Processing. *Joint 7th International Conference on Informatics, Electronics & Vision (ICIEV) and 2nd International Conference on Imaging, Vision & Pattern Recognition (icIVPR)*, 2018, pp. 272-275, DOI: 10.1109/ICIEV.2018.8640956.

21. Poolakkachalil, T. K., Chandran, S., Muralidharan, R., Vijayalakshmi, K. Comparative analysis of lossless compression techniques in efficient DCT-based image compression system based on Laplacian Transparent Composite Model and An Innovative Lossless Compression Method for Discrete-Color Images. *3rd MEC International Conference on Big Data and Smart City (ICBDSC)*, 2016, pp. 1-6, DOI: 10.1109/ICBDSC.2016.7460360.

22. Barannik, V., Tupitsya, I., Sidchenko, S., Tarnopolov, R. The Method of Crypto-Semantic Presentation of Images Based on the Floating Scheme in the Basis of the Upper Boundaries. *IEEE Problems of Infocommunications. Science and Technology (PICS&T): proceedings of International Scientific-Practical Conference*, 2015, pp. 248-251. DOI: 10.1109/ INFOCOMMST.2015.7357326.

23. Wang, Z., Liao, R., Ye, Y. Joint Learned and Traditional Video Compression for P Frame. *IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*, 2020, pp. 560-564. DOI: 10.1109/CVPRW50498.2020.00075.

24. Bui, V., Chang, L., Li, D., Hsu, L., Chen, M. Comparison of lossless video and image compression codecs for medical computed tomography datasets. *IEEE International Conference on Big Data (Big Data)*, 2016, pp. 3960-3962. DOI: 10.1109/BigData.2016. 7841075.

25. Akbari, M., Liang, J., Han, J., Tu, C. Learned Variable-Rate Image Compression With Residual Divisive Normalization. *IEEE International Conference on Multimedia and Expo (ICME)*, 2020, pp. 1-6. DOI: 10.1109/ICME46284.2020.9102877.

26. Shinde, T. Efficient Image Set Compression. *IEEE International Conference on Image Processing (ICIP)*, 2019, pp. 3016-3017, DOI: 10.1109/ICIP.2019. 8803230.

27. Lin, J., Liu, D., Li, H., Wu, F. M-LVC: Multiple Frames Prediction for Learned Video Compression. *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 2020, pp. 3543-3551. DOI: 10.1109/CVPR42600. 2020.00360.

28. Barannik, V., Sidchenko, S., Tupitsya, I., Stasev, S. The application for internal restructuring the data in the entropy coding process to enhance the information resource security. *IEEE East-West Design and Test Symposium (EWDTS)*, 2016, pp. 1-4. DOI: 10.1109/EWDTS.2016.7807749.

29. Artuğer, F., Özkaynak, F. Fractal Image Compression Method for Lossy Data Compression. *International Conference on Artificial Intelligence and Data Processing (IDAP)*, 2018, pp. 1-6. DOI: 10.1109/IDAP. 2018.8620735.

30. Arnob, P., Tanvir, Z.; Prajoy, P., Rafi, A., Muktadir Rahman, M., Mamdudul Haque, Kh., Iris image compression using wavelets transform coding. *2nd International Conference on Signal Processing and In-*

ISSN 1814-4225 (print)
ISSN 2663-2012 (online)

tegrated Networks (SPIN), 2015, pp. 544-548, DOI: 10.1109/SPIN.2015.7095407.

31. Zhu, X., Liu, L., Jin, Na Ai, P. Morphological component decomposition combined with compressed sensing for image compression. *IEEE International Conference on Information and Automation (ICIA)*, DOI: 10.1109/ICInfA.2016.7832096.

32. Wang, S., Kim, S. M., Yin, Z., & He, T. Encode when necessary: Correlated network coding under unreliable wireless links. *ACM Transactions on Sensor Networks*, 2017, vol. 13, no. 1. DOI: 10.1145/3023953.

33. Barannik, V., Tupitsya, I., Barannik, V., Shulgin, S., Musienko, A., Kochan, R., Veselska, O. The Application of the Internal Restructuring Method of the Information Resource Data According to the Sign of the Number of Series of Units to Improve the Statistical Coding Efficiency. *10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS)*, 2019, pp.65-69. DOI: 10.1109/IDAACS.2019.8924460.

34. Phatak, A. A Non-format Compliant Scalable RSA-based JPEG Encryption Algorithm. International Journal of Image. *Graphics and Signal Processing*, 2016, vol. 8, no. 6, pp 64-71. DOI: 10.5815/ijigsp.2016.06.08.

35. Wu, H., Sun, X., Yang, J., Zeng, W., Wu, F. Lossless Compression of JPEG Coded Photo Collections. *IEEE Transactions on Image Processing*, 2016, vol. 25, no. 6, pp. 2684-2696. DOI: 10.1109/TIP.2016.2551366.

36. Lee, J., Cho, S., Beack, S.-K. *Context-adaptive entropy model for end-to-end optimized image compression*, 2018. arXiv: 1809.10452.

37. Chen, C., Zhuo, Y. A research on anti-jamming method based on compressive sensing for OFDM analogous system. *IEEE 17th International Conference on Communication Technology (ICCT)*, 2017, pp. 655-659, DOI: 10.1109/ICCT.2017. 8359718.

38. Wang, S., Kim, S., Yin, Z., He, T. Encode when necessary: Correlated network coding under unreliable wireless links. *ACM Transactions on Sensor Networks*, 2017, vol. 13, no.1, pp. 24-29, DOI: 10.1145/3023953.

39. Han, S., Mao, H., Dally, W. *Deep compression: Compressing deep neural networks with pruning, trained quantization and huffman coding*, 2015. arXiv: 1510.00149.

40. Zhurakovskyi, B., Boiko, J., Druzhynin, V., Zeniv, I., & Eromenko, O. Increasing the efficiency of information transmission in communication channels. *Indonesian Journal of Electrical Engineering and Computer Science*, 2020, vol. 19, no. 3, pp. 1306-1315. DOI: 10.11591/ijeecs.v19.i3.

41. Barannik, V., Tupitsya, I., Dodukh, O., Barannik, V., Parkhomenko, M. The Method of Clustering Information Resource Data on the Sign of the Number of Series of Units as a Tool to improve the Statistical Coding Efficiency. *IEEE 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM)*, 2019, pp. 32-35. DOI: 10.1109/CADSM.2019.8779243.

42. Barannik, V., Tupitsya, I., Gurzhii, I., Barannik, V., Sidchenko, S., Kulitsa, O., Two-Hierarchical Scheme of Statistical Coding of Information Resource Data with Quantitative Clustering. *IEEE International Conference on Advanced Trends in Information Theory (ATIT)*, 2019, pp. 89-92. DOI: 10.1109/ATIT49449.2019.9030451.

43. Barannik, V., Tupitsya, I., Kovalenko, O., Sidchenko, Y., Yroshenko, V., Stepanko, O. The analysis of the internal restructuring method efficiency used for a more compact representation of the encoded data. *Advanced Trends in Information Theory (ATIT'2020): proceedings of the Intern. Conf.*, 2020, pp. 48-51. DOI: 10.1109/ATIT50783.2020.9349307.

44. Khmelevskiy, S., Tupitsya, I., Mahdi, Q. A., Musienko, O., Parkhomenko, M., Borovensky, Y. Development of the external restructuring method to increase the efficiency of information resource data encoding. *Information Processing Systems*, 2021, vol. 3, no. 166, pp. 52-61. DOI: 10.30748/soi.2021. 166.06.

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МЕТОД ТРАНСФОРМАЦИИ АЛФАВИТА ВИДЕОИНФОРМАЦИОННОГО РЕСУРСА ПО КОЛИЧЕСТВЕННОМУ ПРИЗНАКУ

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Предметом изучения в статье есть технологии, реализуемые в современных алгоритмах кодирования видеоизображений с позиции обеспечения соответствующего уровня достоверности в условиях их компактного представления. **Целью** является разработка технологии трансформации алфавита видеоинформационного ресурса по количественному признаку в условиях обеспечения требуемого уровня качества в современных инфокоммуникационных сетях. **Задание:** сформировать требования к видеоизображениям в условиях использования динамических систем видеонаблюдения; провести анализ существующих проблемных факторов, приводящих к дисбалансу между компрессионными и качественными характеристиками существующих алгоритмов кодирования видеоизображений; разработать технологию трансформации алфавита видеоинформационного ресурса по количественному признаку для более выгодного представления кодируемых данных; разработать математическую модель формирования количественного показателя для трансформации видеоизображения; провести анализ эффективности использования разработанной математической модели формирования количественного показателя с позиции обеспечения требуемого высокого уровня достоверности данных видеоинформационного ресурса; провести оценку эффективности разработанной технологии трансформации исходного сообщения по количественному показателю с позиции создания условий для обеспечения более выгодного представления кодируемых данных; исследовать динамику вероятностно-статистических характеристик начального сообщения в результате трансформации по количественному признаку значимости элементов. **Методами** исследований, которые используются, являются методы компрессионного кодирования, реализованные на базе алгоритмов семейства JPEG. Получены следующие **результаты**: в условиях использования динамических систем видеонаблюдения повышаются требования к видеоизображениям. Это связано с наличием дисбаланса между компрессионными и качественными характеристиками существующих алгоритмов кодирования видеоизображений. Компрессионные технологии, реализуемые в алгоритмах на базе платформы JPEG, имеют ряд проблем. Основные из них: сложность алгоритмической реализации, снижение уровня достоверности данных видеоинформационного ресурса в условиях обеспечения требуемого уровня компрессионных характеристик. Для учета указанных проблемных факторов предложен принципиально новый подход – трансформация кодируемых алфавита данных по количественному признаку. Разработана математическая модель формирования количественного признака, определяющая значимость элементов исходного сообщения. **Выводы**. Разработана технология трансформации алфавита исходного сообщения, позволяющая обеспечить создание условий для более предпочтительного представления кодируемых данных за счет значительного повышения динамического диапазона вероятностно-статистических характеристик для трансформированного сообщения в условиях обеспечения требуемого уровня качества видеоизображений.

Ключевые слова: видеоинформационный ресурс; трансформация; алфавит; количественный признак; достоверность; технологии кодирования.

МЕТОД ТРАНСФОРМАЦІЇ АЛФАВІТУ ВІДЕОІНФОРМАЦІЙНОГО РЕСУРСУ ЗА КІЛЬКІСНОЮ ОЗНАКОЮ

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Предметом вивчення у статті є технології, реалізовані в сучасних алгоритмах кодування відеозображень з позиції забезпечення відповідного рівня достовірності в умовах їх компактного представлення. **Метою** є розробка методу трансформації алфавіту відеоінформаційного ресурсу за кількісною ознакою в умовах забезпечення необхідного рівня якості в сучасних інфокомунікаційних мережах. **Завдання:** сформувати вимоги до відеозображень в умовах використання динамічних систем відеоспостереження; провести аналіз існуючих проблемних факторів, що призводять до дисбалансу між компресійними та якісними характеристиками існуючих алгоритмів кодування відеозображень; розробити метод трансформації алфавіту відеоінформаційного ресурсу за кількісною ознакою для більш вигідного представлення кодованих даних; розробити математичну модель формування кількісного показника для трансформації відеозображення; провести аналіз ефективності використання розробленої математичної моделі формування кількісного показника з позиції забезпечення необхідного високого рівня достовірності даних відеоінформаційного ресурсу; провести оцінку ефективності розробленого методу трансформації початкового повідомлення за кількісним показником з позиції створення умов для забезпечення більш вигідного представлення кодованих даних; дослідити динаміку ймовірнісно-статистичних характеристик початкового повідомлення в результаті трансформації за кількісною ознакою значимості елементів. **Методами досліджень**, що використовуються, є методи компресійного кодування, реалізовані на базі алгоритмів сімейства JPEG. Отримано такі **результати**: в умовах використання динамічних систем відеоспостереження підвищуються вимоги до відеозображень. Це пов’язано з наявністю дисбаланса між компресійними та якісними характеристиками існуючих алгоритмів кодування відеозображень. Компресійні технології, реалізовані в алгоритмах на базі платформи JPEG мають ряд проблем. Основні серед них: складність алгоритмічної реалізації, зниження рівня достовірності даних відеоінформаційного ресурсу в умовах забезпечення потрібного рівня компресійних характеристик. Для вирішення зазначених проблемних факторів запропоновано принципово новий підхід – трансформація алфавіту кодованих даних за кількісною ознакою. Розроблена математична модель формування кількісної ознаки, що визначає значимість елементів початкового повідомлення. **Висновки.** Розроблений метод трансформації алфавіту початкового повідомлення, що дозволяє забезпечити створення умов для більш прийнятного представлення кодованих даних завдяки значному підвищенню динамічного діапазону ймовірнісно-статистичних характеристик для трансформованого повідомлення в умовах забезпечення потрібного рівня якості відеозображень.

Ключові слова: відеоінформаційний ресурс; трансформація; алфавіт; кількісна ознака; достовірність; технологія кодування.

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