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# METHOD OF RECURRENT TRUNCATED-POSITIONAL CODING VIDEO SEGMENTS IN UNEVEN DIAGONAL SPACE

*The **subject** of research in this article is methods of encoding transformed video segments to reduce their bit volume without loss of information integrity. The **goal** is to develop a technology for coding uneven diagonal sequences under the conditions of their arbitrary positioning in the transformant. **Task**: to justify the approach of creating new methods of encoding video segments, considering the features of the combinatorial configuration of transformants; to create a method of formatting the coordinate system of spectral components in an uneven diagonal direction; to develop a method of encoding non-uniform diagonal sequences in a two-dimensional spectral space; to build a technology for recurrent realization of the process of sliding truncated-positional coding of uneven-diagonal sequences. The methods used are: mathematical models for estimating the number of structural-combinatorial and psychovisual-combinatorial redundancies in an uneven-diagonal spectral space; methods of positional coding. The following **results** were obtained. Potential advantages of considering the combinatorial configuration of the transformant based on its reformatting according to the non-uniform diagonal structure are substantiated. The technology of recurrent truncated positional coding of video segments in non-uniform diagonal space has been developed. It is based on two technological components. These include: the first component - a pyramidal system of positioning diagonals and their component in the transformant is created. The second component - a method of recurrent implementation of truncated-positional coding of uneven-diagonal sequences, is constructed. Such coding is organized regardless of the positioning of the diagonals in the two-dimensional spectral space of the transformant. Comparative evaluation revealed the advantages of the created method over standardized transformant coding methods. The advantage is achieved by the level of bit volume reduction and reaches an average of 15-30 %. **Conclusions**. For the first time, a method for establishing the coordinates of the components in the diagonals was developed. It is based on considering the features of the structural configuration of the transformant. This creates conditions for reducing time delays for processing video segments. For the first time, a method for recurrent coding of diagonals based on truncated-positional systems was created. This makes it possible to avoid the cases of the violation of the conditions of mutually unambiguous code conversion.*

***Keywords:*** *video information services; video segments; bit volume reduction; transformants; uneven diagonals; truncated-positional coding; combinatorial configurations.*

## Introduction

**The formulation of the problem.** In modern conditions, the state of video information support plays a significant role. This applies to the issues of provision:

1) the complete information of support and decision-making systems. Special attention is paid to receive timely information about the current state of critical infrastructure objects;

2) holistic and up-to-date information for society and the individual.

Video information support is implemented by providing appropriate services using information communication systems (ICS). Among the most popular video services are [1]:

- video conferencing;
- remote video monitoring using stationary and mobile ground and aerospace platforms.

In turn, the effectiveness of their functioning depends on the presence of a balance between the intensity levels of the video information flow and the bandwidth of the information communication network [2].

At the same time, it is necessary to consider the limited bandwidth of the ICS. This is due to the following factors [3]:

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- using the ICS segment, which is based on mobile wireless communication technologies. Such technologies are characterized by a lower transmission speed compared to leading information and communication technologies;

- the occurrence of a complex interference situation during the transmission of information using wireless technologies;

- the presence of events related to the violation of the reliable functioning of the ICS. These include [4]:

a) cybernetic attacks, for example DDoS attacks;

b) errors in the process of designing ICS;

c) destructive actions of the opposing side, which are aimed at destroying or disabling critical infrastructure objects. Including objects of energy and information communication infrastructure. This leads to a significant drop in the bandwidth of the IC.

On the other hand, recently, the demand for video information services has been increasing significantly. Hence, the intensity of the bit stream of video and information traffic increases. The level of intensity exceeds the speed characteristics of modern ICS. In crisis conditions, such an imbalance becomes significant [5, 6].

The consequences of which are the following events:

1. Reduction in the effectiveness of information support systems and decision-making during the management of critical infrastructure components [7].

2. Not timely informing society during emergencies [8].

3. Violation of the process of functioning of dangerous industries (for example, nuclear power plants) [9].

Therefore, the ***scientific and applied problem***, which concerns the lowering of the imbalance between the information load of the information communication network and its bandwidth, is relevant.

**The state of the art**. Solving this problem is complex in nature. One of the components here is the creation of information technologies for coding the video information stream. Such coding is aimed at reducing the bit volume of video data. Accordingly, the level of information load of ICS decreases [10].

The basic technologies here are those that use the JPEG platform [11]. Its basis is formed by the sequence of transformations of video segments. For them, a transitional format is created with subsequent coding and construction of a syntactic binary description [12]. The transitional format is created to increase the potential for reducing the number of different types of redundancy. Examples here are: statistical, structural and psychovisual redundancy of video segments [13].

Among the various types of redundancy for video segments, psychovisual redundancy is the most common [14]. Accordingly, there is a dependence of the level of reduction of the bit volume of the video stream on the amount of psychovisual redundancy. A variety of technological mechanisms are used to eliminate psychovisual redundancy. They include:

- transformations of the color description of the video segment [15];

- reformatting of the macrosegment structure [16];

- thinning of rows and columns of macrosegments [17];

- formation of spectral space [18];

- quantization of the range of components of the spectral space [19].

At the same time, the processes of reducing the amount of psychovisual redundancy lead to the loss of the integrity of video segments. Hence, on the one hand, a reduction in the information load of ICS is achieved. However, on the other hand, the loss of the integrity of video information occurs [20]. Therefore, we have a contradiction between the requirements for ensuring the timeliness of the delivery of video information and its integrity.

To eliminate such a contradiction, it is necessary to create a new class of coding methods. Here it is proposed to use the concepts of establishing and eliminating the number of structural types of redundancy in transformed video segments [21, 22].

**The justification of the approach for creating new methods of encoding video segments.** It is proposed to improve the coding methods toward creating transformations in the spectral space. In this case, a transformant $Y(\alpha,\beta)_{\tau}^{(\ell)}$ is formed. Most often, discrete cosine transformation (DCT) is used to transform a video segment into spectral space. Such a transformation has the following mathematical notation: $\varphi_{dct}: X(\alpha,\beta)_{\tau}^{(\ell)} \to Y(\alpha,\beta)_{\tau}^{(\ell)}$. This formula uses video segment values and transformers considering their positions in the $(\alpha,\beta)$-th macro segment and in the sequence of video frames. That is:

$X(\alpha,\beta)_{\tau}^{(\ell)}$ - $\ell$-th segment in the $(\alpha,\beta)$ -th macrosegment or segment in the $\ell$-th position in the $(\alpha,\beta)$-th macrosegment of the video image with an index $\tau$ in the inter-frame sequence (in the video tensor);

$Y(\alpha,\beta)_{\tau}^{(\ell)}$ - $\ell$-th transformant in the $(\alpha,\beta)$-th macrosegment at the $\tau$-th position in the group of video frames.

The use of spectral description of video segments has advantages. They relate to the possibility of establishing various regularities in the structural content of the transformant [23]. This provides the potential for applying different approaches to evaluate their informativeness.

1. The first approach is based on taking into account psychovisual features regarding the perception of changes in the structural and vivid (SV) content of the video segment [24]. This refers to the fact that:

1) the most informative innovation from the standpoint of psychovisual perception of the video segment is carried by the low-frequency components of the transformer;

2) less sensitivity of visual assessments is manifested to changes in the field of description of small details.

2. The second approach. The heterogeneity of the ranges of changes in the values of the spectral components creates conditions for unevenness [25]:

- the appearance of components in different parts of the transformant;

- according to the distribution law of the probability of occurrence of the values of the components of the transformer. Components that have smaller values may appear more often in the transformant.

3. The third approach considers quantization of the spectral range of the transformant [26]. Hence, the values of the transformer components decrease. There are cases when the value of spectral components will be zero. Such components can form series [27]. A condition is created for the description of such series by the value of their length. That is why the transformant has structural redundancy. At the same time, the length of the specified series is uneven. The longest series length is achieved for the high-frequency region of the transformer. Therefore, there is a dependence of the probability of the appearance of the transformant component on the length of the series. Taking into account such conditional dependencies creates an opportunity to eliminate the structural and statistical redundancy of the transformant [28].

We will generalize the above approaches in relation to set restrictions on the configuration of components in the transformant [29]. This aspect is asserted here. The arrangement of components according to their informative weight in the transformant has characteristic features [30]:

- it is carried out according to certain rules;

- it has certain topological and structural features.

Therefore, restrictions are imposed on possible samples regarding the formation of the transformant content. This is due to its structural and psychovisual features. Thus a combinatorial configuration is formed for the transformant. It is considered a combinatorial object. The specified property of the transformant must be considered in the coding process. For this purpose, the corresponding combinatorial category is used. As such categories, it is proposed to use permutations with repetitions with restrictions on the ranges of changes in the values of its elements. Permutation with repetitions has the following features [31]:

- first, it takes into account both the positions and the very values of the components in the transformer;

- second, the number of permissible permutations with repetitions depends on the value ranges of its components.

In turn, such signs create conditions for:

- accounting for the positions of the components in the transformant. This is necessary for determining the areas of low and high frequencies of the spectral space;

- considering restrictions on the range of changes in component values. This is necessary to account for the unevenness of the spectral range in different parts of the transformant.

Methods of considering the combinatorial restrictions of transformants are described in scientific papers [29, 30]. Here are the following differences:

- the positioning of the components in the transformant is carried out in an even-numbered format;

- spectral ranges are set according to the directions of rows and columns.

However, such methods have certain disadvantages. They are the following:

1. There is an influence of the spectral ranges of the low-frequency region of the transformant on the ranges of the components in its high-frequency region. Then, the ranges of high-frequency components will be excessive relative to their real spectral ranges. Hence, the potential for reducing the number of combinatorial redundancy decreases.

2. There is a need to obtain additional information.

3. The dependence of the reduction of the spectral ranges on the direction of the diagonal bypass of the transformer is not considered.

4. Redundancy caused by a series of components with zero values is not considered.

Therefore, the technology of detecting spectral ranges by rows and columns does not fully consider the combinatorial configuration of the transformer.

To eliminate the mentioned shortcomings, it is suggested to consider the diagonal structure of the combinatorial configuration of the transformant. This will allow:

1) reduce the ranges of changes in component values within individual diagonals;

2) establish cases when the range of changes in component values will be equal to one;

3) consider the tendency of spectral components to form monotonous sequences in diagonal direction.

4) consider the presence of strict monotonicity (increasing or decreasing) for adjacent components of the diagonal. Between the values $y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}$,

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$y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}$ of adjacent components of the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ of the transformant, the following condition is fulfilled:

$$\forall\, y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)} \in Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}:$$

$$y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)} \neq y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}.$$

In this regard, adopt the following designations:

$Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ - $\xi$-a diagonal in the $\ell$-th transformant of the $(\alpha,\beta)$-th macrosegment;

$y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}$ - $\chi$-th component of the $\xi$-th diagonal transformant $Y(\alpha,\beta)_{\tau}^{(\ell)}$.

Thus, it is necessary to develop a technology for encoding transformed video segments. At the same time, it is necessary to consider the peculiarities of their combinatorial configuration in diagonal format.

The development of the technology is based on two established methods.

The first method consists of the created system of diagonally uneven positioning of the components in the transformant according to their uniform coordinates.

The second method concerns the formation of a code value for individual diagonals, considering their unevenness and arbitrary positioning in the two-dimensional spectral space.

Therefore, the ***purpose of the research*** of this article concerns the development of a technology for coding uneven diagonal sequences under the conditions of their arbitrary positioning in the transformant.

## Method of Formatting the Coordinate System of Spectral Components in an Uneven Diagonal Direction

We describe the transformant $Y(\alpha,\beta)_{\tau}^{(\ell)}$ in a diagonal format. It is *proposed* to distinguish two levels of the diagonal format (DF) of the syntactic description of the transformant. The first level consists of setting the configuration of diagonal sequences. To do this, we define the sequence $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ as the $\xi$-th diagonal in the $\ell$-th transform of the $(\alpha,\beta)$-th macrosegment. The transformant $Y(\alpha,\beta)_{\tau}^{(\ell)}$ will then be described by a set of diagonals: $Y(\alpha,\beta)_{\tau}^{(\ell)} = \{Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}\}$, $\xi=\overline{1,\,2n-1}$. Here, $n$ the linear size of the transformant.

The number $\nu_d$ of diagonals depends on the linear size of the transformant. If the linear size of the transformant is $n$, then the number of diagonals is $(2n-1)$, i.e.: $\nu_d = 2n-1$.

The order of indexing diagonals is *proposed* to be determined in the direction starting from the upper left corner to the lower right corner of the transformant. Hence, the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,1)}$, which is located in the upper left corner, has an index $\xi=1$. The diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,2n-1)}$ in the lower right corner has an index $\xi=2n-1$.

The second level of the syntactic format of the transformant concerns the description of individual diagonals. In the general case, the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ is formed by the following set of components $y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}$:

$$Y(\alpha,\beta)_{\tau}^{(\ell,\xi)} = \{y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}\},\ \chi=\overline{1,\,n_{\xi}}.$$

According to the configuration of transformants, their diagonals $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ have the following features.

1. The length $n_{\xi}$ of the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ depends on its location relative to the main diagonal. The main diagonal of the transform is the diagonal with index $\xi=n$. It divides the transformant into two half-zones (triangles). Accordingly, the first half-zone $_{\Delta,1}Y(\alpha,\beta)_{\tau}^{(\ell)}$ includes diagonals if $1 \le \xi \le n$.

2.The lengths $n_{\xi}$ of the diagonals are symmetrical relative to the main diagonal with the index $\xi=n$. Therefore, the equality holds: $n_{\xi} = n_{2n-\xi}$.

3. The length $n_{\xi}$ of the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ is determined by the value of its index $\xi$ in the transformant. The value $n_{\xi}$ is found according to the following formula:

$$n_{\xi} = 2n\cdot \mathrm{sign}(1+\mathrm{sign}(\alpha-1)) - (-1^{\mathrm{sign}\,(1+\mathrm{sign}(-\alpha))})\cdot\xi.$$

In this formula, the disignation is taken: $\alpha=\xi-n$.

Functional $\mathrm{sign}(\alpha-1)$ are used to filter cases when $\xi \le n$ and $\xi > n+1$.

Therefore, the diagonal transformants have an uneven length.

Hence, it can be stated that for the diagonal format of the transformant, the transformation of its structural configuration is carried out. The conversion is made from a uniform row-column format to an uneven pyramidal format.

In this case, the system of positioning components in diagonals will have a sliding character. In this case, the components $y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}$ will be positioned in the transformant by two coordinates, namely:

- the first coordinate is determined by the diagonal index $\xi$;

- the second coordinate is determined by the position $\chi$ of the component in the diagonal.

At the same time, the limits of the index change $\chi$ are uneven and depend on:

- diagonal index $\xi$;

- its belonging to a half-zone $_{\Delta,1}Y(\alpha,\beta)_{\tau}^{(\ell)}$ or $_{\Delta,2}Y(\alpha,\beta)_{\tau}^{(\ell)}$.

Therefore, it is necessary to create a method of binding the uneven diagonal (pyramidal) system of components positioning to the initial uniform system of positioning "row-column". Such binding will allow *the positioning and identification* of diagonals relative to the initial row-column coordinate system of spectral components.

To develop such a binding, it is necessary to create a system of expressions that will allow:

- to build a functional for reformatting the coordinate system of the transformant components;

- determine the coordinates of the diagonal components through their coordinates according to the "row-column" system.

First, let's set the diagonal bypass direction $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$. In general, there are two directions. For the first direction, the bypass is made starting from the lower left. In contrast, for the second option, the bypass has a direction toward the lower left corner of the transformer.

Therefore, in the process of deploying the transformant along the diagonals, the periodicity of the change in the direction of their bypass must be considered. Therefore, it is *proposed* to create a reformatting of the coordinate system of the transformant to an uneven-diagonal (pyramidal) one in two stages.

In the first stage, we will develop a reformatting system without considering the change in the direction of bypassing the diagonals. Accordingly, at the second stage, we will additionally consider such a change.

For certainty, we choose from the beginning the first direction of bypassing the component in the diagonal. Let's establish the dependence between the coordinates of two adjacent components $y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}$, $y(\alpha,\beta,\tau)_{\chi+1}^{(\ell,\xi)}$ diagonals $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ in the "row-column" system. For this purpose, it is suggested to consider the following:

1. The peculiarity of changing the values of the coordinates of two adjacent components $y(\alpha,\beta,\tau)_{i,j}^{(\ell)}$, $y(\alpha,\beta,\tau)_{i+1,\,j-1}^{(\ell)}$ of the diagonal in the "row-column" system. It refers to the existence of a relationship between the coordinates of neighboring components $y(\alpha,\beta,\tau)_{i,j}^{(\ell)}$, $y(\alpha,\beta,\tau)_{i+1,\,j-1}^{(\ell)}$ of the diagonal. The coordinates (i; j) of the next component are determined by recurrent expressions:

$$i := i-1; \quad j := j+1. \qquad (1)$$

Hence, for the coordinates of the two components $y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)}$ and $y(\alpha,\beta,\tau)_{\chi+1}^{(\ell,\xi)}$ in the pyramidal system, the coordinates $(i;\ j)$ and $(i-1;\ j+1)$ of the component will correspond, in the "row-column" system:

$$\{\, y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)};\ y(\alpha,\beta,\tau)_{\chi+1}^{(\ell,\xi)} \,\} \equiv$$

$$\equiv \{\, y(\alpha,\beta,\tau)_{i,j}^{(\ell)};\ y(\alpha,\beta,\tau)_{i+1,\,j-1}^{(\ell)} \,\}.$$

2. The coordinates of the initial component of the diagonal in the "row-column" system depend on its location relative to the main diagonal of the transform. They are calculated by the indices of the corresponding row and column. From here we have:

1) if the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ is located above the main one, $\xi \le n$. The first component $y(\alpha,\beta,\tau)_{1}^{(\ell,\xi)}$ of the diagonal has the following coordinates in the "row-column-column" system: $i = \xi$; $j = 1$. Or $y(\alpha,\beta,\tau)_{1}^{(\ell,\xi)} \to y(\alpha,\beta,\tau)_{\xi,1}^{(\ell)}$. Here, $y(\alpha,\beta,\tau)_{\xi,1}^{(\ell)}$ - the first component of the $\xi$-th diagonal in the "row-column" coordinate system.

The coordinates of the following components of the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ are obtained using expression (1). The pyramidal coordinates of the $\chi$-th component of the $\xi$-th diagonal through the coordinates of the "row-column" system are determined by the formulas:

$$\{\xi-\chi+1;\ 1+\chi-1\} \text{ or } \{\xi-\chi+1;\ \chi\}.$$

The following correspondence is performed:

$$y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)} \equiv y(\alpha,\beta,\tau)_{\xi-\chi+1;\,\chi}^{(\ell)}.$$

Here $y(\alpha,\beta,\tau)_{\xi-\chi+1;\,1+\chi-1}^{(\ell)}$ is the $\chi$-th component of the $\xi$- diagonal in the "row-column" coordinate system.

Hence, the positioning of the components in the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ is given as follows:

$$Y(\alpha,\beta)_{\tau}^{(\ell,\xi)} = \{\, y(\alpha,\beta,\tau)_{\xi-\chi+1;\,1+\chi-1}^{(\ell)} \,\},\quad \chi = \overline{1,\, n_{\xi}};$$

2) if the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ is located below the main diagonal, $\xi \ge n+1$. The coordinates of the first component $y(\alpha,\beta,\tau)_{1}^{(\ell,\xi)}$ of the diagonal in the "row-column" system are determined by the formulas: $i = n$; $j = \xi-n+1$. Then

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$$y(\alpha,\beta,\tau)_1^{(\ell,\xi)} \equiv y(\alpha,\beta,\tau)_{n,\xi-n+1}^{(\ell)}.$$

Here, $y(\alpha,\beta,\tau)_{n,\xi-n+1}^{(\ell)}$ - is the first component of the $\xi$-th diagonal in the "row-column" coordinate system for $\xi \geq n+1$. The correspondence between the two coordinate systems of the diagonal components is described as follows:

$$y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)} \equiv y(\alpha,\beta,\tau)_{n-\chi+1;\, \xi-n+\chi}^{(\ell)},$$

where $y(\alpha,\beta,\tau)_{n-\chi+1;\, \xi-n+\chi}^{(\ell)}$ - $\chi$-th component of the $\xi$-th diagonal, $\xi \geq n+1$.

Hence, the content of the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ is given by the expression:

$$Y(\alpha,\beta)_{\tau}^{(\ell,\xi)} = \{\, y(\alpha,\beta,\tau)_{n-\chi+1;\, \xi-n+\chi}^{(\ell)} \},\ \ \chi = \overline{1,\, n_{\xi}}\,.$$

*Let us now consider the case of the presence of a change in the direction of bypassing the diagonals in the process of unfolding the transformant.* Here it is proposed to take into account the dependence of the direction of the diagonal $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ on the condition of parity of its index $\xi$. If the value of the index is paired, then the diagonal is bypassed in the first direction. On the contrary, for an unpaired one $\xi$, the diagonal is bypassed in the second direction.

To determine the parity condition of the index $\xi$, it is suggested to use the functional $\xi \bmod(2)$ or $\xi \bmod(2) = \xi - [\xi/2]\cdot 2$. Then we have:

- if $\xi \bmod(2) = 0$, then $\xi$ is paired;
- if $\xi \bmod(2) = 1$, then $\xi$ is unpaired.

Then the general system of expressions for ordering the components depending on the direction of the diagonal bypass and its location in the transformant has the following form:

$$Y(\alpha,\beta)_{\tau}^{(\ell,\xi)} = \begin{cases} \{\, y(\alpha,\beta,\tau)_{\xi-\chi+1;\,1+\chi-1}^{(\ell)} \}, \chi = \overline{1,\, n_{\xi}}, \\ \rightarrow \ \xi - [\xi/2]\cdot 2 = 1 \ \&\ \xi \leq n; \\ \{\, y(\alpha,\beta,\tau)_{n-\chi+1;\,\xi-n+\chi}^{(\ell)} \}, \chi = \overline{1,\, n_{\xi}}, \\ \rightarrow \ \xi - [\xi/2]\cdot 2 = 1 \ \&\ \xi \geq n+1; \\ \{\, y(\alpha,\beta,\tau)_{1+\chi-1,\xi-\chi+1}^{(\ell)} \}, \chi = \overline{1,\, n_{\xi}}, \\ \rightarrow \ \xi - [\xi/2]\cdot 2 = 0 \ \&\ \xi \leq n; \\ \{\, y(\alpha,\beta,\tau)_{\xi-n+\chi,n-\chi+1}^{(\ell)} \}, \chi = \overline{1,\, n_{\xi}}, \\ \rightarrow \ \xi - [\xi/2]\cdot 2 = 0 \ \&\ \xi \geq n+1. \end{cases} \quad (2)$$

To generalize the created system of expressions (2), it is suggested to use the following functionals:

1) $\mathrm{sign}(\alpha-1)$ for filtering cases when $\xi \leq n$ and $\xi > n+1$;

2) $\mathrm{comp}(\xi;\, n)$ to compare the values of $\xi$ and $n$.

The functional $\mathrm{comp}(\xi;\, n)$ includes the function $\mathrm{sign}(\alpha-1)$ and is given as follows:

$$\mathrm{comp}(\xi;\, n) = \mathrm{sign}(1+\mathrm{sign}(\alpha-1)) = \begin{cases} 0, \rightarrow \xi \leq n; \\ 1, \rightarrow \xi > n+1. \end{cases} \quad (3)$$

Here $\alpha = \xi - n$.

Then, for different directions of bypass of the components in the $\xi$-th diagonal, we have the following generalization for establishing the aspects between the pyramidal and row-column coordinate systems:

$$y(\alpha,\beta,\tau)_{\chi}^{(\ell,\xi)} = \begin{cases} y_{\xi-\chi+1-\alpha\cdot\mathrm{comp}(\xi;n),\ \chi+\alpha\cdot\mathrm{comp}(\xi;\, n)}, \\ \rightarrow \xi - [\xi/2]\cdot 2 = 1; \\ y_{\chi+\alpha\cdot\mathrm{comp}(\xi;\, n),\ \xi-\chi+1-\alpha\cdot\mathrm{comp}(\xi;n)}, \\ \rightarrow \xi - [\xi/2]\cdot 2 = 0, \end{cases} \quad (4)$$

$$\xi = \overline{1,\, 2\cdot n-1}; \quad \chi = \overline{1,\, n_{\xi}}\,.$$

Formulas (2) - (4) establish the relationship between the coordinates of the diagonal components of two positioning systems: uneven-diagonal (pyramidal) and uniform row-column. Here, the change in the direction of their bypass of the diagonals and their location relative to the main diagonal is considered.

## Method of Encoding Non-Uniform Diagonal Sequences in a Two-Dimensional Spectral Space

Let us consider the process of creating a method for encoding uneven-diagonal sequences in the two-dimensional spectral space of transformants. The coding of the diagonals should consider the features of their combinatorial configuration. It is necessary to ensure the elimination of combinatorial redundancy in the spectral ranges of diagonals. At the same time, it is necessary to ensure the exclusion of the loss of integrity of video segments. It is proposed to organize the encoding of transformant diagonals based on the use of a truncated-positional basis [30, 31]. Code values $E(\alpha,\beta)_{\tau}^{(\ell,\xi)}$ are formed for diagonals $Y(\alpha,\beta)_{\tau}^{(\ell,\xi)}$. Then, the encoding process is described by the following relation:

$$E(\alpha,\beta)_{\tau}^{(\ell,\xi)} = \sum_{\chi=1}^{n_{\xi}} \Delta_{\chi} V(\alpha,\beta)_{\tau}^{(\ell,\xi)};$$

$$\Delta_{\chi} V(\alpha,\beta)_{\tau}^{(\ell,\xi)} =$$

$$=\begin{cases}(y_{\xi-\chi+1-\alpha\cdot comp(\xi;\,n),\,\chi+\alpha\cdot comp(\xi;\,n)}-\\ -\,truncat\,(y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi-1};\,y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi}))\times\\ \times\,(w'(\alpha,\beta,\tau)^{(\ell,\xi)})^{2n\cdot comp(\xi;\,n)-(-1^{sign(1+sign(-\alpha))})\cdot\xi-\chi},\\ \to\ \xi-[\xi/2]\cdot 2=1;\\ (y_{\chi+\alpha\cdot comp(\xi;\,n),\,\xi-\chi+1-\alpha\cdot comp(\xi;\,n)}-\\ -\,truncat\,(y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi-1};\,y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi}))\times\\ \times\,(w'(\alpha,\beta,\tau)^{(\ell,\xi)})^{2n\cdot comp(\xi;\,n)-(-1^{sign(1+sign(-\alpha))})\cdot\xi-\chi},\\ \to\ \xi-[\xi/2]\cdot 2=0.\end{cases} \quad (5)$$

The following designations are used here. The functional for determining monotonicity toward the values of two adjacent components of the diagonal of the transformant:

$$truncat\,(y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi-1};\,y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi})=$$

$$=\begin{cases}sign(1+sign(y_{\xi-\chi+1-\alpha\cdot comp(\xi;\,n),\,\chi+\alpha\cdot comp(\xi;\,n)}-\\ -\,y_{\xi-\chi+2-\alpha comp(\xi;n),\chi-1+\alpha comp(\xi;n)}),\\ \to\ \xi-[\xi/2]\cdot 2=1;\\ sign(1+sign(y_{\chi+\alpha\cdot comp(\xi;\,n),\,\xi-\chi+1-\alpha\cdot comp(\xi;\,n)}-\\ -\,y_{\chi-1+\alpha\cdot comp(\xi;n),\xi-\chi+2-\alpha\cdot comp(\xi;n)}),\\ \to\ \xi-[\xi/2]\cdot 2=0.\end{cases} \quad (6)$$

Expressions (5), (6) make it possible to determine the value $E(\alpha,\beta)^{(\ell,\xi)}_{\tau}$ regardless of the positioning of the current diagonal in the two-dimensional transform. However, the created coding method does not take into account the non-uniformity of the length of the diagonal sequence, i.e. $n_{\xi}=var$ . Therefore, this method can lead to a violation of the conditions of the mutual unambiguity of code conversion.

In turn, this can lead to:

- violation of the syntactic correspondence between the input sequence and its circular value. For example, a situation may occur when the code value is formed for several diagonals of the transformant;

- overflow of the permissible length of the code word.

## Method for Recurrent Realization of the Process of Sliding Truncated-Positional Coding of Uneven-Diagonal Sequences

To exclude such events, it is necessary to develop a *recurrent technology of sliding truncated-positional coding*. The recurrent concept is based on the following principles:

1. The principle of forming the code value starts from the first $y(\alpha,\beta,\tau)^{(\ell,\xi)}_{1}$ component of the diagonal. Therefore, the coding process has a direction toward the smaller elements of the truncated positional number (TPN).

2. The principle of formation of a code value $\Delta^{(\chi)}E(\alpha,\beta)^{(\ell,\xi)}_{\tau}$ under the following conditions:

- by adding the current element $y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi}$;

- taking into account the code value $\Delta^{(\chi-1)}E(\alpha,\beta)^{(\ell,\xi)}_{\tau}$ obtained for the sequence $\Delta^{(\chi-1)}Y(\alpha,\beta)^{(\ell,\xi)}_{\tau}$:

$$\Delta^{(\chi-1)}Y(\alpha,\beta)^{(\ell,\xi)}_{\tau}=\{y(\alpha,\beta,\tau)^{(\ell,\xi)}_{1};...;y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi-1}\}$$

previous elements of TPN.

3. The principle of adding a smaller element $y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi}$ of the TPN. The previous code value $\Delta^{(\chi-1)}E(\alpha,\beta)^{(\ell,\xi)}_{\tau}$ is increased by the value of the spectral range $w'(\alpha,\beta,\tau)^{(\ell,\xi)}$ of the current element $y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi}$ of the TPN.

At the same time, it allows you to control the way of processing elements of the sliding TPN (uneven diagonal sequence). Accordingly, it is *proposed* to check the end of the current diagonal $Y(\alpha,\beta)^{(\ell,\xi)}_{\tau}$ in the process of recurrent coding. The sign here is the processing of its last component $y(\alpha,\beta,\tau)^{(\ell,\xi)}_{n_{\xi}}$. Therefore, the measure of the completion of the coding process of the $\xi$-th TPN consists in checking the ratio between the current number $\chi$ of processed elements and the length $n_{\xi}$ of the TPN. Such a measure is described by the following inequality $\chi<n_{\xi}$. Or with the definition of the value $n_{\xi}$:

$$\chi<2n\cdot comp(\xi;\,n)-(-1^{sign\,(1+sign(n-\xi))})\cdot\xi. \quad (7)$$

Let us now consider the process of rebuilding ratios (5), (6) into the recurrent format. For this purpose, it is proposed to use the concept of the *current code value*. Here, the code value $\Delta^{(\chi-1)}E(\alpha,\beta)^{(\ell,\xi)}_{\tau}$ is formed for the current number $(\chi-1)$ of elements of the sliding truncated-position number. At the same time, the smallest $y(\alpha,\beta,\tau)^{(\ell,\xi)}_{\chi-1}$. This is because the coding is carried out toward decreasing the weight of TPN elements. That is, the direction of coding is chosen from bigger to smaller elements of the TPN. Hence, at each step of the recurrent process, a smaller element of TPN is added.

Accordingly, the beginning of recurrent coding is given by the input condition:

$$\Delta^{(1)}E(\alpha,\beta)^{(\ell,\xi)}_{\tau}=y(\alpha,\beta,\tau)^{(\ell,\xi)}_{1}.$$

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Therefore, the initial (input) code value $\Delta^{(1)}E(\alpha,\beta)_\tau^{(\ell,\xi)}$ is given by the first component $y(\alpha,\beta,\tau)_1^{(\ell,\xi)}$ of the diagonal $Y(\alpha,\beta)_\tau^{(\ell,\xi)}$. Then, according to the second and third principles, taking into account the features of the truncated positional system, we have the following description of the recurrent technology:

$$\Delta^{(2)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \Delta^{(1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} \cdot w'(\alpha,\beta,\tau)^{(\ell,\xi)} + (y(\alpha,\beta,\tau)_2^{(\ell,\xi)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_1^{(\ell,\xi)}; y(\alpha,\beta,\tau)_2^{(\ell,\xi)})) = y(\alpha,\beta,\tau)_1^{(\ell,\xi)} \cdot w'(\alpha,\beta,\tau)^{(\ell,\xi)} + (y(\alpha,\beta,\tau)_2^{(\ell,\xi)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_1^{(\ell,\xi)}; y(\alpha,\beta,\tau)_2^{(\ell,\xi)}))$$

or in the general case for adding the $\chi$-th element of the $\xi$ -th TPN:

$$\Delta^{(\chi)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} \cdot w'(\alpha,\beta,\tau)^{(\ell,\xi)} + (y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)})).$$

The recurrent process of forming the code value $E(\alpha,\beta)_\tau^{(\ell,\xi)}$ for the diagonal $Y(\alpha,\beta)_\tau^{(\ell,\xi)}$ is completed after adding its last element $y(\alpha,\beta,\tau)_{n_\xi}^{(\ell,\xi)}$. That is, we have:

$$E(\alpha,\beta)_\tau^{(\ell,\xi)} = \Delta^{(n_\xi)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \Delta^{(n_\xi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} \cdot w'(\alpha,\beta,\tau)^{(\ell,\xi)} + (y(\alpha,\beta,\tau)_{n_\xi}^{(\ell,\xi)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_{n_\xi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_{n_\xi}^{(\ell,\xi)})).$$

Let us now present the relations describing the recurrent process of formation of the code value for TPN, considering their formation for non-uniform diagonal sequences in the two-dimensional space of the transformant. Here it is necessary to use the system of reformatting the coordinates of the spectral components of the diagonal into the coordinates of the two-dimensional row-column format. Taking into account what we have:

1. In the case of an unpaired value of the index $\xi$ of the current diagonal in the transformant, i.e. $\xi - [\xi/2]\cdot 2 = 1$:

$$\Delta^{(\chi)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} \cdot w'(\alpha,\beta,\tau)^{(\ell,\xi)} + -(y_{\xi-\chi+1-\alpha\cdot\mathrm{comp}(\xi;\,n),\, \chi+\alpha\cdot\mathrm{comp}(\xi;\,n)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)})). \quad (8)$$

In this expression:

1) the component $\Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)}$ is set using the following ratio:

$$\Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \sum_{\gamma=1}^{\chi-1}\Delta_\gamma V(\alpha,\beta)_\tau^{(\ell,\xi)} = \sum_{\gamma=1}^{\chi-1}(y_{\xi-\gamma+1-\alpha\cdot\mathrm{comp}(\xi;\,n),\, \gamma+\alpha\cdot\mathrm{comp}(\xi;\,n)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)})) \times (w'(\alpha,\beta,\tau)^{(\ell,\xi)})^{2n\cdot\mathrm{comp}(\xi;\,n) - (-1^{\mathrm{sign}(1+\mathrm{sign}(-\alpha))})\cdot\xi-\gamma};$$

2) the initial value of the code $\Delta^{(1)}E(\alpha,\beta)_\tau^{(\ell,\xi)}$:

$$\Delta^{(1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = y_{\xi-\alpha\cdot\mathrm{comp}(\xi;\,n),\, 1+\alpha\cdot\mathrm{comp}(\xi;\,n)}; \quad (9)$$

3) the function of determining the direction of monotonicity for the values of two adjacent components of the diagonal of the transformant:

$$\mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)}) = \mathrm{sign}(1+\mathrm{sign}(y_{\xi-\chi+1-\alpha\cdot\mathrm{comp}(\xi;\,n),\, \chi+\alpha\cdot\mathrm{comp}(\xi;\,n)} - y_{\xi-\chi+2-\alpha\mathrm{comp}(\xi;n),\chi-1+\alpha\mathrm{comp}(\xi;n)}). \quad (10)$$

2. In the case of an even value of the index $\xi$ of the current diagonal in the transformer, i.e. $\xi - [\xi/2]\cdot 2 = 0$:

$$\Delta^{(\chi)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} \cdot w'(\alpha,\beta,\tau)^{(\ell,\xi)} + +y_{\chi+\alpha\cdot\mathrm{comp}(\xi;\,n),\, \xi-\chi+1-\alpha\cdot\mathrm{comp}(\xi;\,n)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)})). \quad (11)$$

In this expression:

1) the component $\Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)}$ is set using the following ratio:

$$\Delta^{(\chi-1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = \sum_{\gamma=1}^{\chi-1}\Delta_\gamma V(\alpha,\beta)_\tau^{(\ell,\xi)} = \sum_{\gamma=1}^{\chi-1}(y_{\gamma+\alpha\cdot\mathrm{comp}(\xi;\,n),\, \xi-\gamma+1-\alpha\cdot\mathrm{comp}(\xi;\,n)} - \mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)})) \times (w'(\alpha,\beta,\tau)^{(\ell,\xi)})^{2n\cdot\mathrm{comp}(\xi;\,n) - (-1^{\mathrm{sign}(1+\mathrm{sign}(-\alpha))})\cdot\xi-\gamma};$$

2) the initial (input) value of the code value: $\Delta^{(1)}E(\alpha,\beta)_\tau^{(\ell,\xi)}$:

$$\Delta^{(1)}E(\alpha,\beta)_\tau^{(\ell,\xi)} = y_{1+\alpha\cdot\mathrm{comp}(\xi;\,n),\, \xi-\alpha\cdot\mathrm{comp}(\xi;\,n)}; \quad (12)$$

3) the function of determining the direction of monotonicity for the values of two adjacent components of the diagonal of the transformant:

$$\mathrm{truncat}(y(\alpha,\beta,\tau)_{\chi-1}^{(\ell,\xi)}; y(\alpha,\beta,\tau)_\chi^{(\ell,\xi)}) = \mathrm{sign}(1+\mathrm{sign}(y_{\chi+\alpha\cdot\mathrm{comp}(\xi;\,n),\, \xi-\chi+1-\alpha\cdot\mathrm{comp}(\xi;\,n)} - y_{\chi-1+\alpha\cdot\mathrm{comp}(\xi;n),\xi-\chi+2-\alpha\cdot\mathrm{comp}(\xi;n)}). \quad (13)$$

Thus, relations (7) – (13) provide a mathematical description of the recurrent technology for the implementation of sliding truncated-positional coding of non-uniform diagonal sequences in the two-dimensional space of the transform, regardless of their location relative to the main diagonal. At the same time, the limitation of the length of the diagonal and its unevenness are considered.

## Comparative Evaluation of Video Segment Coding Methods in Spectral Space For a Dynamic Sequence of Video Frames

The developed method is integrated into a standardized technology at the stage of transform processing after quantization. Thus, to obtain transformed video segments, it is planned to use processing stages according to the standardised JPEG platform. At the same time, the developed coding method eliminates additional loss of information integrity.

Let us consider a comparative evaluation of the level $\eta$ of the bit volume of the coded video segment. Two options for encoding transformers have been studied, namely, using created (IM) and existing (PT) technologies [19, 31].

Experimental evaluation is carried out for video segments of three basic types as part of video frames, which have different levels of saturation with small details and structural objects. The type of video segment is determined by the level of its informativeness in terms of structural-semantic content and structural-bright characteristics. The identification of video segments by the specified qualitative and quantitative features is considered in this study [31]. Next, we will use three types of video segments, namely: low-informative (LI), medium-informative (MI) and highly informative (HI). The quantization parameters of the spectral range of the transformant correspond to the level of the peak signal/noise ratio, which is 25 and 45 dB. The results of the experimental evaluation are presented in the form of diagrams in Fig. 1.

Based on the results of the analysis of the given diagrams, the following can be concluded. The level of bit volume for the created transformant coding technology decreases relative to the existing ones:

1) depending on the peak signal noise ratio (PSNR): for the provision mode of 45 dB on average by 30 %; for the provision mode of 25 dB by an average of 17 %;

2) depending on the level of informativeness of video segments: the greatest reduction in bit volume is achieved for highly informative (by 30 %) and medium-informative (by 27 %) video segments in the 45 dB PSNR provisioning mode.

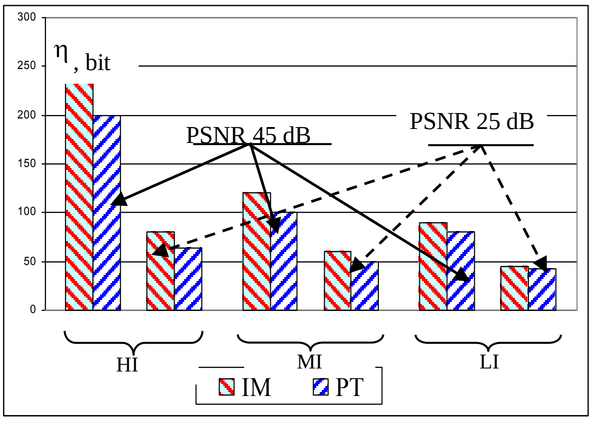


Fig. 1. Diagrams of the dependence of the quantities on the level of informativeness of video segments and the value of the PSNR

Therefore, it can be stated that due to the consideration of the features of the combinatorial configuration of transformants in the non-uniform diagonal coordinate system of its components, the potential for additional reduction of structural-combinatorial and psycho-visual-combinatorial redundancy is achieved by at least 15-30 %, depending on the level of informativeness of the video segment and the level of provision of PSNR. At the same time, such a process does not involve additional distortions during the processing of transformant components.

Comparison of PT and IM methods by the level of integrity of the recovered video frames is carried out by:

- PSNR indicator;
- visual assessment results.

An example of a restored video image using the above methods is shown in Fig. 2.

Fig. 2, a shows the original video image. The video image is classified as low-informative with the presence of objects. Fig. 2, b and Fig. 2, c show the restored video images using the IM PT methods, respectively. For both methods, compression is provided at the level of 27 times.

The following results were obtained:

- visual assessment of the restored video images in Fig. 2 shows the presence of visually noticeable halos on the boundaries of object contours for variant "b";
- the developed method provides an average 8 dB advantage in terms of the value of the PSNR.

## Conclusions

1. The potential advantages of considering the combinatorial configuration of the transformant on the basis of its reformatting according to the uneven diagonal structure are substantiated. This creates conditions for establishing additional dependencies in the structural-spectral content of the transformant.

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a)

b)

c)

Fig. 2. Video image:
a) – Initial video image;
b) – restored using the IM method;
c) – restored using the PT method

2. The technology of recurrent truncated positional coding of video segments in non-uniform diagonal space has been developed. It is based on two technological components. These include:

2.1. The first component. A pyramidal system for positioning diagonals and their component in the transformant has been created. At the same time, binding to a uniform "row - column" coordinate system is ensured. The positioning of the components in the diagonal is ensured regardless of: uneven length of the diagonals; the direction of their bypass; their location relative to the main diagonal of the transformant.

2.2. The second component. A method of recurrent implementation of sliding truncated-positional coding of uneven-uniform-diagonal sequences is constructed. Such coding is organized independently of the positioning of the diagonals in the two-dimensional spectral space of the transformant. The method is based on technological mechanisms that ensure:

- control of uneven length of the diagonal;
- determination of the current code value based on: use of the previous code value; the integration of information about the current element of a truncated positional number.

***Scientific novelty.*** For the first time, a method of establishing the coordinates of the components in diagonals was developed on the basis of considering the peculiarities of the structural configuration of the transformant. The difference in the method is that the identification and positioning of the diagonals in the transformant is carried out:

1) regardless of: the direction of their bypass; location relative to the main diagonal;

2) with simultaneous reference to the uniform "row - column" coordinate system.

This creates conditions for reducing time delays for processing video segments.

For the first time, a method for recurrent coding of diagonals based on truncated positional systems was created. The difference in the technology is that:

- the number of excessive sequences is eliminated. This number results from the equality of the values of two adjacent components of the diagonal;
- the indexing of the components is carried out under conditions of arbitrary location of their diagonal in the transformant.

This makes it possible to avoid the cases of the violation of the conditions of mutually unambiguous code conversion.

3. Due to the consideration of features of the combinatorial configuration of the transformant in the non-uniform diagonal coordinate system, additional reduction of structural-combinatorial and psycho-visual-combinatorial redundancies is achieved. The gain in terms of bit volume reduction reaches at least 15-30 %. The improvement volume depends on the level of informativeness of the video segment and the level of

the provision of PSNR. At the same time, such a process does not involve additional distortions during the processing of transformant components.

***Further research*** concerns the development of a method of truncated positional coding, taking into account the presence of components with zero values in the diagonals of the series.

**Research results are expected to be applied** in the following aspects:

1) as a component of complex technologies of video compression, namely at the stage of encoding transformed video segments;

2) for on-board complexes in the systems of video image formation and transmission;

3) for systems of video monitoring in terms of ensuring the conditions for increasing the resolution of video images;

4) on end nodes of infocommunication networks to reduce their bit load.

**Contribution of the authors:** review and analysis of sources information – **Oleksandr Ihnatiev**; analysis methods for representing video segments in spectral space – **Valerii Kozlovskyi**, **Viacheslav Khlopiachyi**; analysis requirements for the quality characteristics of the provision video information services – **Oleksandr Ihnatiev**; analysis of the shortcomings existing transformer coding methods based on the elimination of psychovisual redundancy – **Roman Onyshchenko**; substantiation of directions for improving coding methods in spectral space – **Sergii Shulgin**; justification of the approach to the interpretation of the transformer as a combinatorial object – **Roman Onyshchenko**; development of a method for formatting transformants according to an unevenly diagonal texture – **Sergii Shulgin**, **Oleksandr Ihnatiev**; development of a model for the representation of diagonal sequences in a truncated-positional space – **Sergii Shulgin**; creating an approach to encoding transformant diagonals according to a sliding scheme – **Vladimir Barannik**, **Sergii Shulgin**; development of a recurrent coding scheme for uneven diagonal sequences – **Sergii Shulgin**, **Oleksandr Ihnatiev**; text of the previous edition of the article – **Vladimir Barannik**; analysis of the results of comparing different methods – **Tatyana Belikova**; selection and use of modeling and charting tools – **Oleksandr Ihnatiev**; editing and post-editing – **Sergii Shulgin**, **Oleksandr Ihnatiev**; formulation of conclusions – **Sergii Shulgin**, **Tatyana Belikova**, **Oleksandr Ihnatiev**.

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## ТЕХНОЛОГІЯ РЕКУРЕНТНОГО УСІЧЕНО-ПОЗИЦІЙНОГО КОДУВАННЯ ВІДЕОСЕГМЕНТІВ В НЕРІВНОМІРНО-ДІАГОНАЛЬНОМУ ПРОСТОРІ

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**Предметом** досліджень в статті є методи кодування трансформованих відеосегментів для зменшення їх бітового об'єму без втрат цілісності інформації. **Метою** є розробка технології кодування нерівномірних діагональних послідовностей в умовах їх довільного позиціонування в трансформанті. **Завдання:** обґрунтувати підхід щодо створення нових методів кодування відеосегментів з врахуванням особливостей комбінаторної конфігурації трансформант; створити метод форматування системи координат спектральних компонент за нерівномірно-діагональним напрямком; розробити метод кодування нерівномірних діагональних послідовностей в двовимірному спектральному просторі; побудувати технологію рекурентної реалізації процесу ковзного усічено-позиційного кодування нерівномірно-діагональних послідовностей. Використовуваними **методами** є: математичні моделі для оцінювання кількості структурно-комбінаторної та психовізуально-комбінаторної надмірності в нерівномірно-діагональному спектральному просторі; методи позиційного кодування. Отримані такі **результати.** Обґрунтовано наявність переваг, які забезпечуються на основі: врахування комбінаторної конфігурації трансформанти; нерівномірно-діагонального форматування трансформанти. Розроблена технологія рекурентного усічено-позиційного кодування відеосегментів в нерівномірно-діагональному просторі. Технологія базується на двох складових, а саме: пірамідальній системі позиціонування діагоналей та їх компонент в трансформанті; рекурентної реалізації усічено-позиційного кодування нерівномірно-діагональних послідовностей. При цьому кодування організується незалежно від позиціонування діагоналей в двовимірному спектральному просторі трансформанти. Для розробленого методу відносно існуючих досягається перевага за рівнем зменшення бітового об'єму, який становить в середньому від 15 % до 30 %. **Висновки.** Вперше розроблено метод встановлення координат компонент в діагоналях на основі врахування особливостей структурної конфігурації трансформанти. Це створює умови для зменшення часових затримок на обробку відеосегментів. Вперше створено метод рекурентного кодування діагоналей на основі застосування усічено-позиційних систем. Це дозволяє уникнути випадків наявності порушень умов взаємно однозначного кодового перетворення.

**Ключові слова:** відеоінформаційні сервіси; відеосегменти; зменшення бітового об'єму; трансформанти; нерівномірні діагоналі; усічено-позиційне кодування; комбінаторні конфігурації.

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