CONSTRUCTING THE CODE DESCRIPTION OF THE TRANSFORMANT DCT TAKING INTO ACCOUNT THEIR STRUCTURAL FEATURES

Natalia Barannik,
National University of Civil Defence of Ukraine
Kharkiv, Ukraine
barannik11121972@gmail.com

Kateryna Zakomorna,
Yaroslav Mudryi National Law University
Kharkiv, Ukraine
malko_ad@ukr.net

Vitaliy Tverdokhlib
Information and Network Engineering department
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
vitalii.tverdokhlib@nure.ua

Nataliya Vorontsova
Kharkiv Medical Academy of Post-Graduate Education
Kharkiv, Ukraine
Vorontsova.Nat.Ev@gmail.com

Eliseev Evgeniy
Senior teacher of the Department of Ivan Kozhedub Kharkiv National University of Air Force,
Kharkiv, Ukraine.
paradox0670@gmail.com

Vitalii Shmakov
Head of Department of Ivan Kozhedub Kharkiv
National Air Force University
Kharkiv, Ukraine
shmakovvital1976@ukr.net

Abstract -**An approach to the construction of a code description of DCT transformants, taking into account the structural features of their binary representation, is presented. It is shown that the proposed model for constructing the code has the ability to reduce the initial number of bits, and also allows you to form a code description of the transformant by a set of independent code blocks. This makes it possible to use this coding method in a video bit rate control system.**

Keywords - bit-plane, bit-rate, DCT-transformant, data compression, codeword, video processing, binary transformant representation

I. INTRODUCTION

As evidenced by existing statistics, today multimedia traffic dominates the network. In this regard, one of the key tasks requiring immediate solutions in the development of information and communication networks are [1-11]:

- providing a compact presentation of video data with the required quality indicators;
- construction of effective mechanisms for adapting the bit rate of video data with the dynamics of the network bandwidth.

In turn, these complex tasks include a number of subtasks, namely [12-15]:

1. The choice of the structural units of the video stream, at the level of which it is supposed to adapt the video intensity and the current parameters of the network bandwidth.
2. More effective, in comparison with standard approaches, reduction of video data volume without quality loss.
3. Construction of an effective code description of the video stream, which allows manipulating the number of structural video fragments that are transmitted to the network in the course of intensity control, without the need for a new code structure.

As part of solving the first subtask, it is assumed that the structural unit at the level of which the adaptation (in fact, control) of the video bit rate to the network bandwidth is performed must meet the following requirements [16-18]:

- relatively small size R in bits to provide flexibility in bit rate control; in this regard, such a structural unit cannot be a frame or a group of frames;
- sufficient volume R bit to quickly reduce the bit rate during control.

Based on the above considerations, the most appropriate structural unit is the DCT transformant.

As part of solving the second problem, it is necessary to reduce a number of types of video presentation redundancies that are not taken into account by existing coding technologies, namely, structural and combinatorial [19, 20].

To do this, it is necessary to use the coding of the binary representation of the DCT transformants, which contributes to the efficient detection of repeated series of bits in the least significant bits of the components as well as in the high-frequency (HF) region of the transformant [3, 4, 6, 21-26].

Finally, to solve the third problem, it is proposed to form the code structures of the DCT transformants by a set of independent code fragments corresponding to separate bit planes of the transformants. In this case, a positional code with unequal weights is the basis for constructing the code structure of DCT transformants.

II. MAIN PART

The first stage of constructing a code structure for a transformant involves its decomposition to a set of separate bit planes according to the following principle [16, 17]:

$$y(q)_{mn} = y_{mn}^{(\nu_{bp})} 2^{\nu_{bp}-1} + y_{mn}^{(\nu_{bp}-1)} 2^{\nu_{bp}-2} + \ldots \quad (1)$$
$$\ldots + y_{mn}^{(\nu_{bp}-\mu)} 2^{\nu_{bp}-\mu-1} + \ldots + y_{mn}^{(2)} 2 + y_{mn}^{(1)},$$

Where $y_{mn}^{(\nu_{bp}-\xi)}$ is the $(\nu_{bp}-\mu)$ th binary element of $(m;n)$ -th component of q -th transformants, $(\nu_{bp}-1) \geq \mu \geq 0$;

$2^{\nu_{bp}-\mu-1}$ is the weighting factor of the binary element $y^{(\nu_{bp}-\mu)}_{mn}$;

ν_{bp} is the number of bits per transform component.

The next step is to identify the lengths of the binary series. Such identification is performed according to the following rules:

- starting from the bit plane with the index $(\nu_{bp}-1)$ up to index 0;
- in the direction of the zig-zag scan on each bit plane [15,17-20].

This allows you to take into account the peculiarities of the distribution of the series of binary elements on each of the bit planes, thereby increasing the compression ratio [3,4 27-43].

Then the meaning of the code $E(q)^{(\mu)}_m$ for m-th sequence of the lengths of the series of binary elements (BEL), on μ-th bit plane q-th transform will be as follows:

$$E(q)^{(\mu)}_\alpha = \ell^{(\mu)}_{\alpha,1}\prod_{\phi=2}^{\Theta_\alpha}(b_\phi+1)+\dots$$

$$\dots+\ell^{(\mu)}_{\alpha,\theta}\prod_{\phi=\theta+1}^{\Theta_\alpha}(b_\phi+1)+\dots+\ell^{(\mu)}_{\alpha,\Theta_m-1}b_{\Theta_\alpha}+\ell^{(\mu)}_{\alpha,\Theta_\alpha}= \tag{2}$$

$$=\sum_{\theta=1}^{\Theta_\alpha}\ell^{(\mu)}_{\alpha,\theta}\prod_{\phi=\theta+1}^{\Theta_\alpha}(b_\phi+1),$$

Where $\ell^{(\mu)}_{\alpha,\theta}$ is a length of θ-th binary series related to α-th BEL sequence within μ-th BP;

$(b_\theta+1)$ is a base element of $\ell^{(\mu)}_{\alpha,\theta}$ considered as an element of a nonequilibrium positional number;

$\prod_{\phi=\theta+1}^{\Theta_\alpha}(b_\phi+1)$ is the weighting factor for length θ-th series;

Θ_α is the number of binary series lengths in α-th sequence.

Here are the bases of nonequilibrium positional numbers; several BEL are set, namely:

$$b_\theta=\psi_{bm}(\ell^{(\mu)}_{\alpha,\theta,1},\dots,\ell^{(\mu)}_{\alpha,\theta,\varphi}), \tag{3}$$

Where $\psi_{bm}(\ell^{(\mu)}_{\alpha,\theta,1},\dots,\ell^{(\mu)}_{\alpha,\theta,\varphi}\}$ is the functional that determines the size of the base b_θ, depending on the length of the binary series;

φ - is the number of BEL, for which a common base is formed b_θ.

To form the bases of positional numbers for a set of binary series lengths, it is necessary to construct two-dimensional arrays using the detected binary series lengths $L^{(\alpha)}_q$:

$$L^{(\mu)}_q=\begin{vmatrix}\ell_{1,1} & \ell_{1,2} & \dots & \ell_{1,\beta} & \dots & \ell_{1,\varepsilon}\\ & & \dots & & & \\ \ell_{\alpha,1} & \ell_{\alpha,2} & \dots & \ell_{\alpha,\beta} & \dots & \ell_{\alpha,\varepsilon}\\ & & \dots & & & \\ \ell_{\upsilon,1} & \ell_{\upsilon,2} & \dots & \ell_{\upsilon,1} & \dots & \ell_{\upsilon,\varepsilon}\end{vmatrix}, \tag{4}$$

Where $\ell_{\alpha,\beta}$ - the value of the $(\alpha;\beta)$-th length of the binary series;

υ and ε are the numbers of rows and columns of the array $L^{(\mu)}_q$.

This will allow calculating the value b_θ for BEL of each line, namely:

$$b(q)^{(\mu)}_\alpha=\max\{\ell_{\alpha,1}\ \ell_{\alpha,2}\dots\ell_{\alpha,\beta}\dots\ell_{\alpha,\varepsilon}\}+1, \tag{5}$$

$$\alpha=\overline{1,\varepsilon}.$$

Array forms $L^{(\mu)}_q$ form υ grounds, i.e. $B_\ell=\{b(q)^{(\mu)}_1,\dots,b(q)^{(\mu)}_\upsilon\}$ where B_ℓ is the base system of the array of binary series lengths.

In this case, the non-equilibrium positional numbers are the columns of the array $L^{(\mu)}_q$.

Accordingly, this reduces the number of bases in number ε. This in turn reduces the number of discharges. $W(B_\ell)$ to describe the bases of positional numbers to a value that is insignificant compared to the total length of codewords $W(E(q)^{(\mu)}_\alpha)$ containing data on quantities $E(q)^{(\mu)}_\alpha$ - code values of positional numbers. Therefore, the quantity $W(B_\ell)$ can be neglected.

Array $L^{(\mu)}_q$ formed in the direction of the columns. In this regard, the quantity υ (the length of the column of the BEL array) is chosen so as to ensure that the condition is met:

$$W(E(q)^{(\mu)}_\alpha)\le W, \tag{6}$$

Where W is the length of the code word.

Here you can use the property of the BEL detection operation - the formation of new series begins for each bit plane.

Hence, the maximum length L_{max} of binary series will not exceed the value uv, i.e .:

$$L_{max}\le uv, \tag{7}$$

Where uv is the number of binary elements in the bit plane.

Then the maximum number of digits $\upsilon([\ell og_2 L_{max}]+1)$ for description υ elements of the BEL array column is limited by the value $\upsilon([\ell og_2 uv]+1)$:

$$W(E(q)^{(\mu)}_\alpha)\le\upsilon([\ell og_2 L_{max}]+1)\le\upsilon([\ell og_2 uv]+1). \tag{8}$$

Hence, the length of an array column $L_q^{(\alpha)}$, at which the codeword does not overflow, is calculated as:

$$\upsilon \le \frac{W}{([\ell og_2 uv]+1)}. \tag{9}$$

After that, it calculates ε -number of array columns $L_q^{(\mu)}$, namely:

$$\varepsilon=[\frac{H}{\upsilon}]+1, \tag{10}$$

Where H is the total number of BEL of the total bit transformants representation.

Building an array $L_q^{(\mu)}$ of BEL is constructed provided that the value of the quantity H initially unknown (since the filling of the array is performed as the binary series is detected), and in the column of the array $L_q^{(\mu)}$ both the sequence of BEL obtained for the entire bit transformants representation and the sequence of BEL generated for one bit-plane can be included.

With this in mind, this process includes the following steps:

1) for $\alpha=1$ and $\beta=1$, the element is being formed $\ell_{1,1}$ equal to $\ell_{1,1}=\ell_1$ where ℓ_1 is the length of the first binary series obtained for the bit representation of the transform;

2) if on $(\alpha;\beta)$-th step element value $\ell_{\alpha,\beta}$ it was equal $\ell_{\alpha,\beta}=\ell_\varphi$ where ℓ_φ is the length of φ-th binary series, then for $\upsilon(\beta-1)+\alpha < H$, in other words, over the array $L_q^{(\mu)}$ not all formed binary series lengths are distributed, the expression $\ell_{\alpha,\beta}=\ell_{\varphi+1}, \to \alpha \le \upsilon$ or $\ell_{1,j+1}=\ell_{\varphi+1}, \to i > s$. Otherwise, for $\upsilon(\beta-1)+\alpha = H$ the calculation process will be completed, $\upsilon_\varepsilon=\alpha$, and $\varepsilon=\beta$.

In this case, the maximum value of the code nonequilibrium positional code $E(q)_\alpha^{(\mu)}$ will not exceed the value of the accumulated product of the bases of its elements, i.e.:

$$E(q)_\alpha^{(\mu)} \le \begin{cases} \prod_{\alpha=1}^{\upsilon} h_\alpha, \to \beta < \varepsilon; \\ \prod_{\alpha=1}^{\upsilon_\varepsilon} h_\alpha, \to \beta = \varepsilon, \end{cases} \tag{11}$$

Where h_α is defined as the largest value of all elements of a string in an array of binary series lengths.

It follows that:

- calculation of the positional number code is possible using information about the bases of positional numbers and does not require additional service information;

- code redundancy is reduced, which is explained by the fulfillment of the following inequality:

$$h_\alpha \le uv, \tag{12}$$

which is caused by the limited values of BEL.

The final code structure of the transform will look like Fig. 1

$E(\nu_{bp}-1)_1^{(\mu)}$,	$E(\nu_{bp}-1)_2^{(\mu)}$,	…	$E(\nu_{bp}-1)_\alpha^{(\mu)}$,	…	$E(\nu_{bp}-1)_\upsilon^{(\mu)}$,
		…			
$E(q)_1^{(\mu)}$,	$E(q)_2^{(\mu)}$,	…	$E(q)_\alpha^{(\mu)}$,	…	$E(q)_\upsilon^{(\mu)}$,
		…			
$E(1)_1^{(\mu)}$,	$E(1)_2^{(\mu)}$,	…	$E(1)_\alpha^{(\mu)}$,	…	$E(1)_\upsilon^{(\mu)}$,
$E(0)_1^{(\mu)}$,	$E(0)_2^{(\mu)}$,	…	$E(0)_\alpha^{(\mu)}$,	…	$E(0)_\upsilon^{(\mu)}$,

Fig. 1. The scheme of DCT-transformant codogram formation

In Fig. 1, the lines of the code structure correspond to the individual bit planes are transformative and contain ε code values of positional numbers.

Therefore, by manipulating the amount q lines of code structure, you can control the total number of bits per transform description.

III. CONCLUSION

A model of coding for the DCT transformant as a fragment of a video frame is obtained, based on non-equilibrium positional coding.

This model takes into account the structural features of constructing transformants in a binary description, namely, the concentration of sequences of binary elements in the high-frequency zone as well as the least significant bits. This helps to reduce the code and structural-combinatorial redundancies of the description of the transform.

Therefore, it helps to reduce the number of bits to describe it. The proposed model forms a codogram in the form of a set of independent code modules, some of which can be eliminated during video bit rate control.

The minimum compression ratio of the proposed method depends on the decrease in the values of the deviations of the lengths of the binary series from the thresholds of the multiplicity of the power of 2.

The gain achieved in this case in terms of the compression ratio for the minimum value of such a deviation relative to the maximum is no less than 1.5 times. In addition, an increase in the length of a series entails an increase in such a gain by an average of 15%.

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