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CONTROLLING THE PARAMETERS OF COMPRESSION OF VIDEO FRAMES USING A BITWISE TRANSFORMANTS TRANSMISSION

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Викладено основні аспекти організації методу контролю параметрами компресії, у якому трансформанта розглядається як тривимірний об'єкт. Це дозволяє контролювати бітову швидкість, шляхом порозрядної передачі трансформант, з урізанням ряду бітових площин відповідно до вимог до рівня допустимої помилки. В ролі механізму прийняття керуючих рішень використовується метод динамічного програмування, базований на принципі оптимальності Беллмана. Наведено спосіб організації даних для даного методу контролю, з урахуванням принципів методу послідовного наближення технології Progressive JPEG. Описано математичну модель методу управління. Обґрунтовано необхідність зниження числа станів алгоритму, а також пропонуються методи, що сприяють зменшенню числа станів, що збільшує швидкодію алгоритму, базовану на поділі трансформант за ступенем складності.

Ключові слова: управління бітовою швидкістю, бітова площина, трансформанта, компресія.

It outlines the main aspects of the organization of the method of control parameters of compression, in which the transformant considered as the three-dimensional object. This allows controlling the bitrate by bitwise transmission transforman witht truncating a number of bit planes in accordance with the level of the allowable error. As a mechanism for making operating decisions, using dynamic programming method, based on the principle of Bellman's optimality. It provides a way to organize data for this method of control, taking into account the principles of the method of successive approximations technology Progressive JPEG. A mathematical model of the control method presented. Shown the necessity of reducing the number of states of the algorithm and suggests methods that reduce the number of states, thereby increasing the speed of the algorithm based on the division of the transformant according to the degree of difficulty.

Keywords: bit rate control, bit-plane, transformant, compression.

Introduction

For sustainable operation of videoconferencing and video streaming service, in terms of growth of their users is to reduce the intensity of the current video traffic at end nodes. This problem can be solved using the methods of controlling the parameters of compression. This can ensure the effectiveness of broadcast video data in a dynamically changing network parameters. The main reason for the low efficiency of some of existing methods for controlling the parameters of compression — that they ignore the dynamics of the broadcast stream, whereby fragments of different informative are compressed at the same rate [1].

The proposed method considers the use of bitwise transforms the transmission frame and the difference between the degree of complexity of the transformant.

Thus constructed control promotes the harmonization of the broadcast stream to the characteristics of the network of channels selected quality setting.

Presentation of transformant in three-dimensional space to organize the bit-rate control

The source video frame is regarded as a set F of blocks:

$$F = \sum_{p=1}^{Q} q_p, \quad (1)$$

where the q_p — p-th block of size $m \times n$.

Each of blocks q of a video frame, after converting the RGB color model to a model YCbCr, subjected to DCT-transformation. The result is a set P of transforms:

$$P = \sum_{p=1}^{Q} Y_p, \quad (2)$$

where Y_p — p-th transform of frame.

Each transformant represented by a set of components:

$$Y_p = \left\| Y(p)_{hw} \right\|, \quad (3)$$

where $Y(p)_{hw}$ — (h;w) p-th component of p-th transformant.

Component $Y(p)_{hw}$ of Y_p transformant is represented as a sequence of bits, describing the presentation of the corresponding element in binary form. This is equivalent to the transformation

$$\left\| Y(p)_{hw} \right\| \to \left\| \left\langle \alpha(p)_{hw}^{k-1}, \ldots \alpha(p)_{hw}^{m}, \ldots \alpha(p)_{hw}^{0} \right\rangle^T \right\|, \quad (4)$$

$$\alpha(p)_{hw}^{k} \in \{0,1\};\; h=\overline{0,7};\; w=\overline{0,7};\; k=\overline{7,0},$$

where the $\alpha(p)_{hw}^{k}$ — $k-th$ bit of binary expansion of $(h;w)-th$ component of $p-th$ transform.

The totality of all the elements of $k-th$ layer of $p-th$ transformant is a *bit plane* $y(p)_k$.

The set of binary representations of all elements of the matrix Y_p is a bit cube. Further, we agree that we will consider an 8-bit representation of the transformants

Presentation of the transformants in three-dimensional space allows to organize layered data, the basis of which is the method of successive approximations of Progressive JPEG technology [2].

In this case, it is possible to control the compression of the image [3].

The essence of the control is that the transmission can be sent to only a part of the channel layers, thereby reducing the weight of the image.

Data organization for development of the bit rate control algoritm by presentation transformants in three-dimensional space

To determine the layers, needed to transfer, is necessary to set for every $p-th$ transformant the transmission vector $V(p)_k$ of transformants bit planes, which corresponds to the binary representation of numbers $k-1$ up to 0:

$$V(p)_k = \left\langle v(p)_k^{k-1},...,v(p)_k^{m},...,v(p)_k^{0} \right\rangle \quad (5)$$

Each option of transmitting layers will correspond to the transformant Y_p', which corresponds to the original Y_p, but differ in the degree of distortion d_p with respect to the original.

Thus, after setting of the transmit vector of bit planes, the transmitting sequence $TS(p)_k$ can be formed for $p-th$ transformant for a given vector $V(p)_k$:

$$TS(p)_k = v(p)_k^{k-1} \& ...v(p)_k^{0} \& (\, y(p)_k \,|\, v(p)_k = 1). \quad (6)$$

Each item of this sequence takes 1-bit. At the beginning of the sequence placed bits of the vector $V(p)_k$, the totality of which determines the numbers $v(p)_k^{m}$ of transmitting layers of bit cube. If the $k-th$ bit of vector of transmission is 1, then transfers all the 64 elements $\alpha(p)_{hw}^{k}$ of the layer k. If transmission vector corresponding bit is 0, the bit values of the layer of bit cube are not transmitted.

The algorithm for generating the sequence for the transmission of $p-th$ transformant for a given vector $V(p)_k$ consists of these steps:

1. Reset the $TS(p)_k$ string.

2. Calculate the transmission vector $V(p)_k$.

3. Add the layers of bit cube according to vector $V(p)_k$:

$$TS(p)_k = V(p)_k \,\&\, y(p)_k. \quad (7)$$

To determine the number of non-zero units of the transmission vector uses value $K1(V(p)_k)$.

It defines the size of the transmitted sequence and, accordingly, the bit rate of compression of $k-th$ transformant:

$$r_k(V(p)_k) = 8 + 64 \times K1(V(p)_k). \quad (8)$$

Thus, codeword length, with 8-bit representation of the transformants, will be in the range of from 72 to 520 bits (from 9 to 65 bytes).

Bit cube Y_p assembly operation on the receiving side is composed of a sequence $TS(p)_k$ of the following steps:

1. Reset the bit cube: Y_p'.

2. Accept the $V(p)_k$ vector (the first 8-bit of sequence $TS(p)_k$).

3. Fill in the bit cube elements for the layers, that correspond to non-zero bits in the vector of transmission: if the bit of vector of transmission is 1, the values of the following 64 bits are filled with the corresponding layer of the bit cell of the cube; if the element is equal to 0, then added to the cube of the layer 0 elements.

Justification of the need of reducing the number of states of the algorithm, as a component of the overall transnission delay

A key attribute of the algorithm of control of the parameters of the compression rate is rate of formation of the code, that affects the transfer delay introduced by the frame when it is processed on the transmission side.

Delay Δt, incurred in the transmission of video frames with P blocks, and represented by the series of components, defines as follows:

$$\Delta t = \sum_{p=1}^{Q}(t_c + t_{cont} + t_b^t) + t_{tr} + \sum_{p=1}^{Q}(t_b^r + t_d), \quad (9)$$

where t_c — the transformants encoding time, defined by baseline compression algorithm; t_b^t and t_b^r — time of insertion of compressed fragment into the buffer on the transmission side and extraction from the buffer on the reception side, respectively.

These values are the characteristics of implementing devices and determine their computing power; t_{tr} — the transmission time of compressed fragment to recipient, defined by bandwidth B_w; t_d — decoding time. Its value depends on the method of display of received frames.

Progressive JPEG technology uses two methods to display:

1. Display "on the fly". Each received scan at the same time sequentially displayed on the display device.

2. Displays the entire frame. For the developed method, this approach is preferable, because, unlike the display "on the fly", does not create an additional processing load on the decoder; t_{cont} — time of control algorithm. This value is in the chosen by basis (dynamic programming) control method is determined by the number of transforms, forming the frame, as well as the number of bit planes (bit) components of transformant.

As previously shown [4], the number of choices of bit planes for the same frame is:

$$W = (2^k)^p, \quad (10)$$

where k — the number of bit planes to represent one component of transformants; p — number of transformants of frame.

Reduction of the number of states reduces the time t_{cont}, which would otherwise can reach unacceptable values, exceeding the ITU-T requirements for latency streaming broadcast and interactive video.

Methods of reducing the number of states of the algorithm based on the differentiation of transformants in terms of complexity

Therefore, two approaches are available to reduce the number of states.

Both approaches use the division of processed transformants into categories, based on terms of complexity.

In the first approach, for each transformants calculates estimate of the complexity (saturation) K_{sat} of the block.

The starting frame block is represented as a two-dimensional array $h \times w$.

Next, for each of the rows of the array is the maximum $K^i_{\max}$ and minimum $K^i_{\min}$ values of the coefficients. It calculates the saturation index K_{sat}, as the sum of the differences between the maximum and minimum ratio for all lines:

$$K_{sat} = \sum_h \sum_w \left(K^i_{\max} - K^i_{\min} \right). \quad (11)$$

If the resultant value of K_{sat} does not exceed a certain threshold K_{th}, the unit is considered as unsaturated. Otherwise, it is assumed that the block may be saturated.

Transformants, were included in the saturated category, transferred in full, bit by bit, starting with the MSB.

For the medium saturated transformants, produced the truncation of a number of bit planes (LSB), thus, reduces the size of k and hence the set W.

Low saturated transformants are discarded, ie vector for the transmission of such a transformant is not evaluated, forming of zeros. In this case, the value P decreases, thereby reducing the size of the set W.

For the second approach is also used by the computation of complexity of transformants. Specifies the maximum $K^i_{\max}$ and minimum $K^i_{\min} = 0$ values of the terms of difficulty.

The full range of obtained values of K_{sat} is divided into n groups from n to 0. Each group corresponds to a particular set $V(p)_k$ of vectors of transmission (see Table).

Example of selection table of $V(p)_k$, based on value of K_{sat}

Value of K_{sat}	An array of vectors of transmission $V(p)_k$
K^1_{sat}	11111111 11111110 11111101 ...
...	...
K^n_{sat}	... 00000010 00000001 00000000

With taking this into account information of table, for a plurality of choices W for the frame is valid:

$$W = \Lambda^n \quad (12)$$

where Λ number of vectors $V(p)_k$ in the corresponding group.

Thus, the block processing time is reduced.

The compression algorithm of the frame in this case consists of the following stages:

1. Set zero value to the transmission sequence line.
2. Calculate K_{sat} value.
3. Associate K_{sat} with a group of vectors $V(p)_k$.
4. Determine the appropriate transfer vector $V(p)_k$.
5. Generate the transmitted sequence.
6. Encode transmitted sequence by Huffman.

In this case, the $n-th$ group contains the vector $V(p)_k$, corresponding to the transfer of all bit planes transformants; zero group — vector $V(p)_k$, containing zeros.

This approach allows narrow down search space $V(p)_k$ by going to the entire set of values to the sub-band, defined in magnitude K_{sat}.

Creating the tables of ratios K_{sat} and $V(p)_k$ requires the additional empirical researches to determine the number of required groups K_{sat}^i and their dimension.

In establishing of compliance should also take into account the peculiarities of conformity K_{sat} and $V(p)_k$ for different types of motion, namely:

– frames, containing computer graphics;

– frames with the information of the photographic nature;

– frames of the combined type.

Using the dynamis programming method for computing the set of $V(p)_k$ vectors for the frame

For the calculation the optimal $V(p)_k$ values, uses a dynamic programming which is based on the Bellman equation. For the application of the principle of Bellman two conditions must be [5]:

1. "The lack of aftereffect", which determines that the state of the system is independent of the decisions taken in the previous steps.

2. The objective function to be additive.

In this case, there are P decision points count transformant frame.

For each transformants select a transfer vector $V(p)_k$, which corresponds to the decision at this stage.

Formally, articulate the problem can be as follows: find a combination of vectors for transmission of a video in the transformant a three-dimensional representation, which will provide a minimum bit rate for given bandwidth:

$$\begin{cases} r_{(F)} \to \min; \\ d_{(F)} \le d_{\min}; \\ r_{(F)} \le B_w. \end{cases} \quad (13)$$

Bit rate $r_{(F)}$ and value of $d_{(F)}$ for the entire frame F, taking into account formula (1) are additive. Thus, summary values of $r_{(F)}$ and $d_{(F)}$ calculates in this way:

$$\begin{cases} r(F) = \sum_{p=1}^{P} r_p \\ d(F) = \sum_{p=1}^{P} d_p \end{cases}, \quad (14)$$

where r_p — bit rate of $p-th$ transformant of frame; d_p — level of the standard deviation of $p-th$ transformant.

Each solution is a strategy U for the transfer of the frame, which forms many private policies, defined for each transformant:

$$U = \{U_p\},\ p = \overline{1,P}. \quad (15)$$

Each private strategy U_p corresponds to the bit rate $r_p = r(U_p)$, which determines the number of bits in the transmitted sequence, formated to transformant Y_p.

The best strategy U^* would be next, which corresponds to the lowest bit rate. It shows as a sequense of private strategies for all the P transformants:

$$U^* = \{U_p^*, U_{p-1}^*, ..., U_0^*\}. \quad (16)$$

Also evaluated the quality of perception transmitted transformants $r_p = r(U_p)$.

Given index can be calculated to sending the sequence to the channel and can used for evaluating the chosen strategy in terms of quality of compression.

For calculations is enough estimation on the assumption, that the transmission channel "perfect", i.e. transmits information without distortion.

Limitation of bandwidth B_w defines by specifications of communication channels.

Limitation on the total level of the standard deviation d_p is defines based on the required level of quality of visual perception of stream.

In the studied problem, such as the transition function from state to state, but there interconnectedness selected private strategies at the level of restrictions. Thus, the strategy that provides the lowest bit rate may be defined as follows:

$$U^* = \left\langle v^*(p)_k^{k-1}, ..., v^*(p)_k^m, ..., v^*(p)_k^0 \right\rangle, \quad (17)$$

where $v^*(p)_k^m$ — vector of transmission for the $m-th$ transformant, providing private optimal strategy in $m-th$ step.

Under the principle of Bellman's optimality, for each p− th vector of transformant transmission $V(p)_k$ is selected so that together with the transfer vectors considered transformant (i.e., a transformant from $p+1$ to P) formed to have sequence of transmission of minimum length when the predefined restrictions on $r_{(F)}$ and $d_{(F)}$, accordance with the conditions (13). Application of the scheme involves the solution of Bellman in two passes.

The first the passage from step P to first determine the value of the optimal bit rate. The second pass allows to determine the optimal strategy for the control of values of vectors $V(p)_k$ of transmission for each transformant.

The set of admissible strategies for each step is formed taking into account the following requirements:

1. Exclusion from a consideration of strategies that lead to a buffer overflow.

2. Exclusion from a consideration of strategies for which the total error exceeds given.

3. Strategy with the same values of $d_{\min}$ are excluded from consideration, with the exception those, for which $r_p = r_{\min}$.

4. Strategy with the same value r_p are excluded from consideration, except those, for which $d_p = d_{\min}$.

Conclusions

1. It is developed a method of data forming for bit rate control method, that based on the three-dimensional representation of transformant and organization the bitwise transmitting for its. Transmitting data consideres as a sequence of combined transmitting vector, with set of transformant bit-planes.

2. Proposed the bit rate control method, that controls the sequence of transmitting bit planes of transformant. Thus, controls the size of transmitting data. For the controlling method proposed the dynamic programming method as a subject of making controlling decisions.

Scientific novelty. For the first time concerning a method of reducing the number of states of control algorithm, based on division of transformants by complexity. For the first time proposed a technique of downing search space of number of states of algorithm by going from the entire set of values to the sub-band, defined in magnitude of complexity of transformant.

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