Chapter 19
Complex Method of Video Stream Intensity Control

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Abstract Consider the construction of a video stream bit rate controlling method, based on the non-equilibrium positional coding of a transformants bit representation. Developed the concept of combined use of technologies, which allows to adapt the video data intensity to the channel bandwidth in the conditions of its dynamic change.

Keywords Video stream intensity · Bit plane · Bandwidth · DCT transformant · Transformants bit representation

19.1 Introduction

Coding technologies used to reduce the intensity R video signal, do not fully provide the possibility of matching the intensity R of the output video stream with bandwidth B_w of the network. This is the cause of network congestion, as well as the irrational use of the network. As a result, the requirements are not met QoS regarding the main quality indicators of video services—packet delays, jitter value and loss factor, which is the reason of the overall decrease in video quality of the receiving side [1–7].

The reason for the inconsistency of the quantities R and B_w is the impact of a number of different factors affecting their dynamics.

On the one hand, the dynamics of bandwidth B_w of the network depends on the nominal network bandwidth, network congestion factor, interference factor, topolog-

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S. Zawiślak and J. Rysiński (eds.), *Engineer of the XXI Century*, Mechanisms and Machine Science 70, https://doi.org/10.1007/978-3-030-13321-4_19

ical features of the network, the indicator of traffic intensity depending on the time of day and the degree of complexity of traffic [4–14].

On the other hand, bit intensity R of the video stream per Ω frames, is formed as a sum of bit intensities $R^{(i)}$ of the individual frames F_i. Value $R^{(i)}$ is a variable that depends on the structural and semantic content of a particular frame, whether the frame belongs to one of the types: I, P or B, the type and codec parameters. Hence, the intensity R of the video stream will vary according to the varying intensity of individual frames.

Therefore, to ensure efficient transmission of video data, it is required to match the intensity of the video stream entering the channel with the dynamics of changing of the network bandwidth. Such a process includes among other things management and localization of the intensity of video data. In this connection, it is required to develop a method for controlling the bit rate of the video stream.

19.2 Method Requirements

The condition for initializing the method, in the process of video translation, is exceeding the total load of the output buffer R_Σ higher than the control level R_{cont}:

$$R_\Sigma > R_{cont} \tag{19.1}$$

The following basic requirements are imposed on the method of managing the intensity of video tracking:

- provide real-time video processing [13–18];
- ensure the preservation of the reliability of information. The character and number of errors, introduced in the process of traffic intensity management, should not significantly influence the required level of reliability [17–20];
- consider the dynamics of changes in network throughput in the process of work.

To meet these requirements, it is necessary to select the mechanisms involved in processing video data inputting to the output buffer and capable of changing their intensity, depending on changes in network capacity [18–20]. These are such mechanisms:

1. The process of frame formation F_i η in slices $S^{(\eta,i)}$, in turn, the slice $S^{(\eta,i)}$ is formed by Q with the help of transformants $Y^{(q,\eta,i)}$. Here transformant is a result of the frame block discrete-cosine transformation, leads to transforming of an image fragment from a spatial to a spectral representation. To quickly reduce the intensity R below than R_{cont}, it is proposed to manipulate the number of transformations of the slice. Then when the buffer R_Σ is loaded above the reference level, you can achieve a decrease in the load below the level $R_\Sigma < R_{cont}$ for the minimum number of steps. At the same time, the level of the error introduced in

this way will be less significant, than when you manipulate the number of larger structural units of the video stream—by slices or frames.

2. Non-equilibrium positional encoding of the bit representation of transformants. At this stage, the binary description of the transformant is performed. In this case, the code $C(q)^{(\eta,i)}$ of the transformant is a set of code structures $C(q)^{(\mu,\eta,i)}$ of the individual bit planes, which is equivalent to the expression:

$$C(q)^{(\eta,i)} = \sum_{\mu=1}^{n} C(q)^{(\mu,\eta,i)} \tag{19.2}$$

The code description of the bit plane, in turn, consists of code constructions of non-equilibrium positional numbers (NEPN) [19].

This approach allows us to consider the transformant as an array of separate independent objects, which can be further used for additional correction of video intensity.

19.3 Bit Rate Control Technologies

Based on the selected mechanisms, participating in the processing of video stream, technologies of changing the intensity of the video stream are developed.

19.3.1 Transformant Interpolation Technology

The technology is aimed at rapidly reducing the intensity of the video at the first stage of the method, when conditions (19.1) are satisfied.

The technology assumes consistent reduction of the number of Q transformant of the slice $S^{(\eta,i)}$ of the frame F_i before reaching the load level R_Σ of the buffer below the reference value R_{cont}. This is achieved by increasing the interpolation step λ. For an arbitrary step λ of interpolation, the bit rate of the slice is:

$$R(\lambda)^{(q,i)} = \sum_{q=1}^{Q} R^{(q,i)} - \sum_{k=1}^{\lambda} R^{(k,i)} = \sum_{q=1}^{Q-\lambda} R^{(q,i)}, \tag{19.3}$$

where $\lambda = \overline{0, Q-2}$, since to restore the slice on the receiving side it is necessary to have at least 2 transformants. These transformants are considered to be basic.

If the value $\lambda = Q - 2$ is reached but a decrease in the buffer load to the value $R_\Sigma < R_{cont}$ is received, then the interpolation step remains equal to $Q - 2$. Further decreasing in the buffer load is achieved by applying the technology of eliminating bit planes $Y(\mu)^{(q,i)}$ of the basic transformants.

19.3.2 The Technology of Eliminating Bit Planes of Base Transformants

This technology is applicable if, as a result of processing the video stream using interpolation technology of transformants, the maximum interpolation step is reached, but the conditions (19.1) continue to be implemented. This situation is described by the following relationship:

$$\begin{cases} \lambda = Q - 2 \\ R_{\Sigma} \geq R_{cont} \end{cases} \tag{19.4}$$

Initially, for the description of the transformant n bit planes are used. To reduce bit intensity $R^{(q,\eta,i)}$ of the transformant, an exception is made for ϑ bit planes $Y(q)^{(\mu,i)}$ used to represent it. First, the bit planes are ranked in order of decreasing the mean square error level (MSE) $d(\vartheta)^{(q,i)}$ so that the highest bit-plane index corresponds to the maximum level $d(\vartheta)^{(q,i)}$.

After ranking, sequential elimination of the bit planes is performed, starting with $\vartheta = 1$, corresponding to the introduction of a minimum error. An exception is executed until the pack drops the buffer load level, or the value $\vartheta = n - 1$ is reached.

Eventually, ϑ-th step technology, each of the basic $Y^{(q,\eta,i)}$ of the transformant of the slice is represented as $n - \vartheta$ bit planes.

Bit rate of the slice $S^{(\eta,i)}$ of the i-th frame in the process of excluding bit planes of basic transformants, taking into account the fact that the maximum, K-th interpolation step, is calculated using the formula:

$$R(K, \vartheta)^{(\eta,i)} = \sum_{\mu=1}^{n-\vartheta} R(\mu, d)^{(1,i)} + \sum_{\mu=1}^{n-\vartheta} R(\mu, d)^{(Q,i)} \tag{19.5}$$

where $R(\mu, d)^{(1,i)}$ and $R(\mu, d)^{(Q,i)}$—respectively are bit intensity of the first and Q-th basic slice transformants.

Elimination of bit planes leads to error $D^{(q,\eta,i)}$ growth of the transformant [20], as shown by formula:

$$D^{(q,\eta,i)} = \sum_{\vartheta=1}^{\sigma} d(\vartheta)^{(q,i)}, \quad 1 \leq \vartheta \leq n - 1 \tag{19.6}$$

where ϑ—number of excluded from further consideration bit planes of the transformant;

$d(\vartheta)^{(q,i)}$—error caused by the exception of the q-th transformant of the frame F_i.

If the final error $D^{(\eta,i)}$ of slice $S^{(\eta,i)}$, being the total error value $D^{(q,\eta,i)}$ of the transformants exceeds the permissible level, the error correction technology is applied at the next stage of the method.

19.3.3 *The Technology of Eliminating the Bit Planes of Added Basic Transformants*

The technology is used in the case when the buffer load is reduced, but the level of the resulting slice error exceeds the reasonable D^{min}:

$$\begin{cases} R_{\Sigma}(t_n) < R_{cont} \\ D^{(\eta,q,i)} \geq R_{min} \end{cases} \quad (19.7)$$

In this case, to describe the slice $S^{(\eta,i)}$ δ of the added transformant is introduced.

To do this step, λ is lowered, for the description of the slice with an additional δ-th transformant from the range $\overline{Y^{(2,\eta,i)}, Y^{(Q-1,\eta,i)}}$ is entered.

Further bit planes $Y(\mu)^{(\delta,i)}$ of the added basic transformant are ranked in descending order MSE, similar to the ranking adopted in the technology of eliminating bit planes of basic transformants.

Then, a number of bit planes is manipulated to describe the added basic transformant.

After performing the ranking of bit planes, $\phi = n - 1$ bit planes of lower order orders of the added basic transformant $Y(\mu)^{(\delta,i)}$ are temporarily excluded.

Therefore, at this step, the added basic transformant is represented by a single bit plane $Y(\mu)^{(\delta,i)}$, making the maximum value $d(\mu)^{(\delta,i)}$ MSE in case of its exclusion.

Further, the bit rate of the slice $S^{(\eta,i)}$ is performed according to formula:

$$R^{(\eta,i)} = \sum_{q=Q-1}^{Q-\lambda} R^{(q,\eta,i)} + \sum_{\delta=1}^{Q-\lambda-1} \sum_{\phi=n-1}^{0} R(\phi)^{(\delta,i)}, \quad \lambda = Q - 2 \quad (19.8)$$

where $\sum_{q=Q-1}^{Q-\lambda} R^{(q,\eta,i)}$—contribution to the bit rate of the slice, possessing q basic transformants under the condition, that at least one transformant has been interpolated;

$\sum_{\delta=1}^{Q-\lambda-1} \sum_{\phi=n-1}^{0} R(\phi)^{(\delta,i)}$—contribution to the bit rate of the slice, introduced by δ added basic transformants, under the condition of exclusion from each ϕ bit planes.

If the value $R^{(\eta,i)}$ obtained at this step leads to overflow of the buffer above the reference value, a decision to reduce the number of the added basic transformants by one is made.

After this, the frame is transferred to the channel with the previously obtained values λ and the way of presenting the basic transformants, when $R^{(i)} < R_{cont}$.

In the case when the obtained value $R^{(\eta,i)}$ does not lead to buffer overflow, evaluation of the current MSE slices is performed, as shown by the following formula:

$$D^{(\eta,i)} = \sum_{q=2}^{\lambda-1} D^{(q,\eta,i)} + \sum_{\mu=n-\phi}^{n} d(\mu)^{(\delta,i)}, \quad n - 1 \leq \phi \leq 0, \quad (19.9)$$

where ϕ—the number of the excluded (at this step) bit planes of the added basic transformant.

In this case, if the value $D^{(\eta,i)} \geq D_{\min}$, a decision is made to further reduce MSE. For this, the quantity ϕ is decreased by one due to inclusion in the added basic transformant $Y^{(\delta,s,i)}$ of the bit plane corresponding to the next ranking position by the amount of reduction introduced MSE.

Further, as at the first step, we estimate the quantities $R^{(\eta,i)}$ and $D^{(\eta,i)}$ slice according to formulas (19.7) and (19.8). If the values obtained at this and all subsequent steps correspond to conditions (19.7), i.e. decline MSE to the required level $D^{(\eta,i)} < D_{\min}$ is not received, but buffer overflow does not occur, at each step the value of ϕ successively decreases by one. In this case, for each ϕ MSE and buffer loading level are estimated. Thus, there is a gradual decrease $D^{(\eta,i)}$ MSE of the slice $S^{(\eta,i)}$ with a simultaneous increase in bit intensity $R^{(\eta,i)}$.

The value ϕ is found effective at a certain stage of correction of MSE, at which the next conditions are satisfied:

$$\begin{cases} R_{\Sigma} < R_{cont} \\ D^{(i)} \leq D^{\min} \end{cases} \tag{19.10}$$

19.4 Conclusions

The ways of reducing the bit rate of the video stream in the conditions of changing the network capacity are proposed. The joint use of the developed technologies allowing:

- ensure the processing of the video stream with minimal time delays;
- promptly respond to changes in the bandwidth of the channel;
- to correct the level of the introduced error during processing.

As shown by experimental studies, the developed method allows to match the bit rate of the video stream with the bandwidth of the channel without restrictions on the range of speeds, in contrast to standard methods such as SBR [21]. In this case, the method starts working already at the beginning of the video broadcast

In terms of further improvement of the proposed method, it is required to develop an effective method for interpolation of transformants, to minimize the level of introduced errors in the stage of interpolation.

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