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POSSIBLE VIDEO SEQUENCES CODING APPROACH

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МОЖЛИВИЙ ПІДХІД ДО КОДУВАННЯ ВІДЕОПОСЛІДОВНОСТЕЙ

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ВОЗМОЖНЫЙ ПОДХОД К КОДИРОВАНИЮ ВИДЕОПОСЛЕДОВАТЕЛЬНОСТЕЙ

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Abstract. A possible approach to the encoding of video sequences based on the separate implementation of interframe and intraframe decorrelation is proposed. At the interframe decorrelation stage, a block representation structure of I, P, B frames with prediction based on the use of a motion vector for each of the blocks is applied. At the intraframe decorrelation stage, it is proposed to use an algorithm based on the wavelet representation of the entire frame with the implementation of the combined compression method by using adaptive restriction to the minimum of decomposition level signals, using the quantization bit depth of decomposition level signals depending on their number, which is similar to frequency-dependent quantization adopted in JPEG standard, the use of decorrelation with prediction of signals of decomposition levels sequence, as well as the use bitplanes code signal decomposition prediction. Evaluation of the proposed approach was carried out by image transformations mathematical modeling in the MATLAB environment at the stage of intraframe decorrelation for images with varying degrees of criticality to lossy compression. The ratio of the peak value of the signal to the coding

interference was used as a criterion. As the results of mathematical modeling have shown, a multiple bitstream reduction can be achieved while maintaining a high image quality compared to bitstream reduction, which can be achieved if encoding methods based on the MPEG-4 AVC and MPEG-4 HEVC standards are implemented. The implementation of the proposed approach is likely to complicate and increase the cost of hardware and software, increase the signal delay during processing, complicate the procedure for selecting encoding parameters and resolve compromise issues. However, it can be assumed that a gain in encoding efficiency will more than cover the possible costs.

Key words: video sequence, coding, decorrelation, compression, wavelet conversion, bit rate, image quality.

Анотація. Пропонується можливий підхід до кодування відеопослідовностей на основі роздільного здійснення міжкадрової і внутрішньокадрової декореляції. На етапі міжкадрової декореляції застосовують блокову структуру представлення I-, P-, B-кадрів с передбаченням, заснованим на використанні вектора руху для кожного з блоків. На етапі внутрішньокадрової декореляції пропонується використовувати алгоритм на основі вейвлет-представлення всього кадру з реалізацією комбінованого методу стиснення шляхом використання адаптивного обмеження за мінімумом сигналів рівнів декомпозиції, використання розрядності квантування сигналів рівнів декомпозиції в залежності від їх номера, що подібно частотно-залежному квантуванню, прийнятому в стандарті JPEG, використання декорреляции з прогнозом сигналів послідовності рівнів декомпозиції, а також використання передбачення бітових площин коду сигналів декомпозиції. Оцінка запропонованого підходу здійснювалася шляхом математичного моделювання в середовищі MATLAB перетворень зображення на етапі внутрішньокадрової декореляції для зображень з різним ступенем критичності до стиснення зі втратами. Як критерій було використано відношення пікового значення сигналу до шуму кодування. Як показали результати математичного моделювання, може бути досягнуто багаторазове скорочення швидкості цифрового потоку при збереженні високої якості зображення в порівнянні зі скороченням швидкості цифрового потоку, яке може бути досягнуто в разі реалізації методів кодування, заснованих на стандартах MPEG-4 AVC і MPEG-4 HEVC. Реалізація запропонованого підходу, швидше за все, призведе до ускладнення й подорожання апаратури і програмного забезпечення, збільшення затримки сигналу в процесі обробляння, ускладнення процедури вибору параметрів кодування і рішення питань компромісу, проте можна припустити, що виграш в ефективності кодування з лишком окупить можливі витрати.

Ключові слова: відеопослідовність, кодування, декореляція, стиснення, вейвлет-перетворення, швидкість цифрового потоку, якість зображення.

Аннотация. Предлагается возможный подход к кодированию видеопоследовательностей на основе раздельного осуществления межкадровой и внутрикадровой декорреляции. На этапе межкадровой декорреляции применяют блочную структуру представления I-, P-, B-кадров с предсказанием, основанным на использовании вектора движения для каждого из блоков. На этапе внутрикадровой декорреляции предлагается использовать алгоритм на основе вейвлет-представления всего кадра с реализацией комбинированного метода сжатия путем использования адаптивного ограничения по минимуму сигналов уровней декомпозиции, использования разрядности квантования сигналов уровней декомпозиции в зависимости от их номера, подобно частотно-зависимому квантованию, принятому в стандарте JPEG, использование декорреляции с прогнозом сигналов последовательности уровней декомпозиции, а также использования предусмотренного битовых плоскостей кода сигналов декомпозиции. Оценка предложенного подхода осуществлялась путем математического моделирования в среде MATLAB преобразований изображения на этапе внутрикадровой декорреляции для изображений с разной степенью критичности к сжатию с потерями. В качестве критерия были использованы отношение пикового значения сигнала к шуму кодирования. Как показали результаты математического моделирования, может быть достигнуто многократным сокращением скорости цифрового потока при сохранении высокого качества изображения по сравнению с сокращением скорости цифрового потока, которое может быть достигнуто при реализации методов кодирования, основанных на стандартах MPEG-4 AVC и MPEG-4 HEVC. Реализация предложенного подхода, скорее всего, приведёт к усложнению и подорожанию аппаратуры и программного обеспечения, увеличение задержки сигнала в процессе обработки, усложнению процедуры выбора параметров кодирования и решения вопросов компромисса, однако можно предположить, что выигрыш в эффективности кодирования с лихвой окупит возможные затраты.

Ключевые слова: видеопоследовательность, кодирование, декорреляция, сжатие, вейвлет-преобразование, скорость цифрового потока, качество изображения.

Currently, TV broadcasting and other video applications use image compression according to the MPEG-2 Video [1], MPEG-4 AVC [2] and MPEG-H HEVC [3] standards. A new standard MPEG-5 Video [4] is under development, which, while maintaining the same level of compression efficiency as HEVC, will allow this efficiency to be realized at a lower cost. Recommendation ITU-T H-263 [5] standardized a large number of coding methods, the use of which can lead to further increase in efficiency at subsequent stages of technology development, when it becomes appropriate.

The requirements for the compression of video sequences in TV production and TV broadcasting systems are defined in Recommendation ITU-R BT.1203 [6] for segments of the TV through path under various transmission conditions, including on the basis of an acceptable reduction in the quality of the reconstructed image. The requirements for video sequence compression in the SDTV systems are defined in Recommendation ITU-R BT.1380 [7], and compression is implemented according to the MPEG-2 and MPEG-4 AVC standards. The requirements for video sequence compression in HDTV and UHDTV systems are defined in Recommendation ITU-R BT.1737 [8], which defines the use of compression according to MPEG-4 AVC and MPEG-H HEVC standards. Recommendation ITU-R BT.1870 [9] defines encoding parameters according to these standards in case it is used in relation to a digital terrestrial broadcasting system. Recommendation ITU-R BT.2073 [10] defines the HEVC encoding parameters for broadcasting in HDTV and UHDTV systems.

All of these regulatory documents provide coding video sequences in the form of interframe decorrelation and intraframe lossy coding based on the use Discrete Cosine Transform (DCT). In this case, the image is divided into blocks in combination with motion vector block use. As for inter-frame coding, it is employed using a motion vector for inter-frame prediction of information of individual blocks. In this case, the block representation of the image is used to implement compression of inter-frame differences. In terms of intraframe coding, the use of DCT-based compression has limitations, the fact of which was taken into account when developing the JPEG-2000 still image compression standard [11]. This standard defines coding images that can be divided into tiles. Moreover, one tile can have arbitrary sizes, including the size of full frame. Thus, it is possible to take into account local properties of the image.

The criterion for assessing image quality in systems using encoding can be peak video signal level to the encoding noise level the ratio (PSNR). Recommendations ITU-R BT.1683 [12] and ITU-T J.144 [13] adopted as the main criterion a similar relationship, defined on the transmitted scene objects edge areas (EPSNR). These recommendations define an appropriate quality evaluation algorithm using wavelet coding as an example, in which case the EPSNR criterion can be considered as the most suitable.

It seems obvious that if the capabilities of intraframe coding according to the algorithms defined by the JPEG-2000 standard were implemented in relation to video sequences coding standards in combination with the set of techniques established in the above standards, it would be possible to further increase the efficiency of coding of video sequences.

The MPEG-4 AVC and MPEG-H HEVC standards provide, in particular, the use of wavelet coding for some special situations. In the JPEG-2000 standard, the use of wavelet coding is fundamental.

In [14, 15, 16], an integrated approach to the implementation of the wavelet coding of still images was proposed, combining possible methods of implementing image processing for individual levels of decomposition and it was shown that the use of this approach in systems with wavelet coding can lead to a significant increase the compression ratio while maintaining the high quality of the restored image.

The following text provides examples of a possible rating to reduce the digital image stream for wavelet coding with 9 levels of decomposition for the case of representing the image signals with brightness Y and color-difference signals C_B, C_R in the 4: 4: 4 format with 12-bit digital coding

for two values of the relative level of restriction by the minimum of signals from the 1st to 8th decomposition levels: $\alpha = 5\ \%$ and $\alpha = 10\ \%$. These estimates depend on the spatial frequency and bit representation of the signals at the corresponding decomposition levels from 1 to 8 with bits: 2, 2, 3, 6, 6, 8, 9, 12, respectively; prediction of signals of orders of decomposition from the 7th to 1st according to signals of orders of the 8th to 2nd using their spline interpolation; as well as predictions of the bit planes of the higher bits on the bit planes of the lower bits, respectively.

Table 1 presents the used test images with estimates of detail, the criterion of which is the relative area occupied on the image by the contour signals for two levels of limitation for the luminance and color components. Based on these estimates, one can judge the statistical properties of the image, from which the coding efficiency depends, in particular, according to the combined method of wavelet compression, for which the presented estimates are obtained.

Table 1 – Test images parameters

Title	Image	Detail					
		Y		C_B		C_R	
		$\alpha = 5\ \%$	$\alpha = 10\ \%$	$\alpha = 5\ \%$	$\alpha = 10\ \%$	$\alpha = 5\ \%$	$\alpha = 10\ \%$
Religious building		2.1	1.6	1.4	0.7	1.1	0.24
Tree on the rocks		2.6	1.8	0.93	0.5	1.23	0.71
Railway station		8.6	6.2	3.7	2.5	5.2	3.1
Music room		13.6	9	2.3	0.5	3.6	1.1

Tables 2 and 3 show the estimates of PSNR and EPSNR in channels Y, C_B, and C_R, as well as compression ratio and encoding parameters for the above algorithm. From these estimates it follows that the use of the proposed combined algorithm for intraframe decorrelation will allow highly efficient coding with a decrease in the bit stream rate of more than 100 times with almost imperceptible image distortions.

Table 2 – Image distortion parameters and compression ratio for $\alpha = 5\ \%$

Image title	PSNR & EPSNR						Compression ratio		
	Y		C_B		C_R		Y	C_B	C_R
	PSNR	EPSNR	PSNR	EPSNR	PSNR	EPSNR			
Religious building	47.2	50.4	44.8	46.6	45.1	49.2	132.3	162.4	171.6
Tree on the rocks	49.4	52.6	45.4	47.3	46.8	50.3	118.6	171.5	156.4
Railway station	45.4	51.1	48.3	52.4	47.3	51.2	153.8	156.2	166.3
Music room	48.7	52.5	46.7	49.9	49.6	53.2	109.7	112.7	107.5

Table 3 – Image distortion parameters and compression ratio for $\alpha = 10\ \%$

Image title	PSNR & EPSNR						Compression ratio		
	Y		C_B		C_R		Y	C_B	C_R
	PSNR	EPSNR	PSNR	EPSNR	PSNR	EPSNR			
Religious building	45.8	48.3	43.6	45.4	42.7	46.5	144.7	176.5	183.2
Tree on the rocks	46.3	47.7	44.1	46.3	43.5	47.4	127.1	178.3	146.6
Railway station	45.0	46.8	41.7	43.6	43.2	45.5	162.3	168.4	171.0
Music room	46.9	49.8	44.8	48.7	46.2	49.1	134.5	129.7	126.3

The approach proposed in this paper to the encoding of video sequences based on the separate implementation of interframe and intraframe decorrelation allows to increase significantly the degree of compression of video sequences. At the interframe decorrelation stage, the block structure allows using the motion vector to predict each of the blocks in the next frames. At the stage of intraframe coding, an option is proposed to use a complex algorithm based on the wavelet transform. This algorithm proposes: an adaptive limitation on the minimum of signals at each of the levels of decomposition, as well as additionally regulating the bit depth of the signals depending on the number of levels of decomposition (which is similar to frequency-dependent quantization adopted in the JPEG standard). In addition, the prediction of decomposition level signals and of bit planes for the code of decomposition signals is introduced, which can significantly increase the compression ratio while maintaining high image quality.

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