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JAKOŚCIOWA ESTYMACJA SKOMPRESOWANYCH PLIKÓW VIDEO TYPU DVC Z ZASTOSOWANIEM TRANSFORMACJI FALKOWYCH

Streszczenie: W artykule rozważa się zastosowanie system DVC do przesyłu obrazów wideo o wysokiej-rozdzielczości. W proponowanym systemie stosuje się hierarchiczne transformaty falkowe. W przypadku kodowania typu DVC, złożoność rachunkowa analizy sygnału (ramek obrazu) jest charakterystyczna dla dekodera. Po stronie transmisji sygnału, enkoder używa współczynników niskich częstotliwości ósmego i dziewiątego poziomu do dekompozycji transformat falkowych jako kluczowych ramek/klatek. Co druga ramka jest pomijana, ale jest interpolowana w dekoderze przez kluczowe ramki, ponadto uwzględnia się dodatkowe informacje zawierające współczynniki falkowe do predykcji błędów. W pracy dokonano porównania pakietów oprogramowania tj. dokonującego fragmentacji oraz codec-a DISCOVER, uwzględniano/kasowano błędy logiczne związane z proporcją „sygnału-do-szumu". Dokonano estymacji złożoności różnych sekwencji video. Uwzględniono dodatkowe kryterium BD-PSNR.

Słowa kluczowe: : transformacja falkowa, kompresja obrazu, cyfrowe przetwarzanie sygnałów, cyfrowy potok/strumień danych

QUALITY ESTIMATION OF DISTRIBUTED VIDEO CODEC BASED ON WAVELET TRANSFORM

Abstract: This paper considers the implementation of distributed video coding of high-definition video sequences based on hierarchical wavelet transform. With distributed video coding, the computational burden of frame prediction is mainly borne by the decoder. On the transmitting side, the encoder uses the low frequency coefficients of eight and nine levels of wavelet transformation decomposition as key frames. Every second frame is skipped and is interpolated in the decoder by key frames and additional information containing wavelet coefficient prediction errors. Comparison of the fragmented software package and the

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DISCOVER codec was carried out according to the fallacies of the signal-to-noise ratio in the bitrate. It is understood that the complexity of the movement and is estimated for different video sequences will be based on the analysis of the fragmented algorithm for generating additional information for the additional criterion BD-PSNR.

Keywords: wavelet transform, image compression, digital signal processing, digital stream

1. Introduction

Distributed video coding (DVC) is based on Slepian-Wolf theory and Wiener-Ziv theory, independently encodes two or more independent distributed sources, and then uses one decoder to use inter-source correlation for all encoded sources, performing joint decoding [1, 2, 3]. The difference between distributed video coding and the technical standards of conventional video coding technology is generally used to make full use of redundant video signal information on the coding side. The complexity of encoding is typically 5 to 10 times that of decoding, which is suitable for cases where the video signal is encoded one or more times (for example, TV broadcast, video on demand, video disc storage), and distributed video encoding reduces the complexity of the encoder. For mobile transmission devices, it uses low power consumption of the encoder, shows good fault tolerance, which is suitable for some wireless video terminals (such as wireless video surveillance systems, video sensor networks) with limited computing power, memory space and power consumption [4].

The distributed encoding method can be considered as the original hierarchy information to generate additional information on the receiving side and transmitted through the reverse channel for control, thereby restoring the original information according to the information related to the source.

In this paper, a software model of distributed video coding is proposed, in which only low-frequency coefficients of the highest levels of wavelet transform decomposition are used as key frames.

2. Hierarchical wavelet decomposition

On the transmitting side, each frame of the video sequence is transferred to the spectral region based on the wavelet transform. For high-definition images, it is possible to decompose into nine levels, while only significant coefficients of low-frequency components are preserved at the eighth and ninth levels. However, information about the high frequency components can be extracted from the low frequency ones. For each frame on the receiving side, the reverse wavelet transform reconstructs the image, including the high-frequency coefficients by the interpolation method [5, 6]. In the encoder, frames are decimated and only every second of the video sequence is transmitted. Based on two received frames, a motion vector is formed on the receiving side and compared with the coefficients of the received second frame. This section is devoted to minimizing motion vector prediction errors.

The Slepian-Wolf theorem belongs to the category of lossless coding [1], which basically indicates the range of code rates for distributed coding. The hypothesis that the two are independent and equally distributed infinitely long random sequences, and the entropies X and Y are the probability distributions H(X) and H(Y) respectively, and the code rates are RX with RY. The joint entropy is the set H(X, Y), H(X|Y) with H(Y|X) conditional entropy. When using entropy encoding plus decoding, RX with RY, the value ranges

$$RX \geq H(X), RY \geq H(Y) \quad (1)$$

Because there is a correlation between X and Y, it may be relevant to use X and Y individually encoded together to decode. This not only reduces the code rate, but also achieves the same information rate as with joint coding. The lower bound of the given lossless coding rate of distributed information according to the Slepein-Wolff theorem.

The Slepane-Wolf coding theorem justified the use of distributed lossless video coding, and Wiener-Ziv proved its application to the field of lossy coding [2]. When the extended information range is set, the bit rate is available only at the end of decoding and generating a lossy source coding rate distortion theory. When encoding X Y, the side information used by the party when encoding X and Y is prohibited, and only the X decoder is used when decoding. When decoding to obtain a reconstructed image, a key distortion value is set.

Scheme of the experiment for comparative evaluation of the developed algorithms

In order to carry out a sequential evaluation of different algorithms in the DVC scheme, the onset of progress is beaten [7]. A new codec scheme is implemented, within the framework of which all algorithms in all modules are fixed. A similar codec should be considered a reference codec. In one of the modules of the codec, the algorithm is changed for testing. The codec modifications are subject to testing. The reference and test codecs are run on one set of video sequences and the results are compared with the curves of "speed-change": it is important that the curve is better, it is quicker to evaluate the algorithm in the DVC scheme.

The main problem that is to blame for this approach is that the codec modules work together in a collapsible system, which is a high emergent one. In connection with in distant subdivisions for dermal fragmentation within the framework of this algorithm, a description and results of a number of experiments are given, as it is necessary to demonstrate in order to demonstrate the winning over of this algorithm in the DVC scheme. At the end of the experiment, a split video codec was introduced, which includes the split algorithm, with the DISCOVER codec, which is respected by the base implementation of the split video codec, as well as with the basic standard video compression algorithms [8, 9].

The ratio of the broken software package and the DISCOVER codec according to the “speed-change code” curves is shown

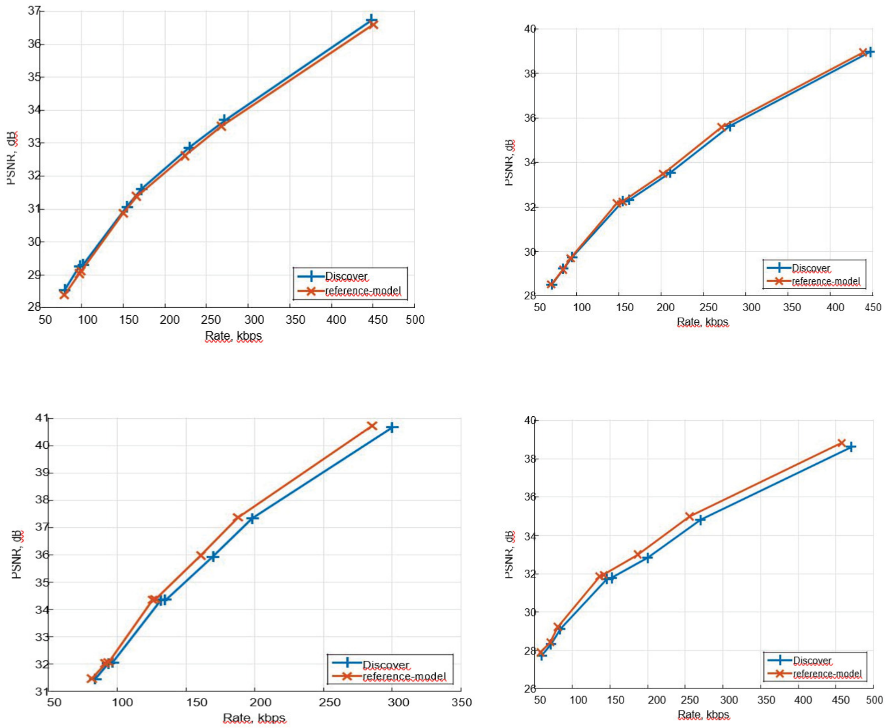


Figure 1. Comparison between the split software package and the DISCOVER codec according to the curves of "speed-change"

Methods of evaluating algorithms for generating side information

As it was shown in section II of this work, the basis of algorithms for generating side information is the inter-frame prediction procedure based on time interpolation [9]. The more accurately the interpolation of intermediate frames is performed, i.e. the more the frame approximated on the decoder side is similar to the corresponding frame on the encoder, the less errors between frame predictions will be contained in the side information of the decoder [10]. Thus, to conduct a comparative analysis of side information generation algorithms, it is enough to compare the results of time interpolation obtained using the basic algorithm used in the software complex and the developed algorithm. It should be noted that the observation of this comparison should be carried out using experiments of two types.

1. Comparison without taking into account the features of the distributed codec.
2. Comparison within the distributed codec framework.

The experiment of the first type allows you to judge the algorithm of inter-personnel prediction as a whole. If at this stage there is no gain compared to the reference algorithm, then with a high probability the use of this algorithm will not give a gain in the DVC scheme either. The experiment of the second type allows you to get an understanding and approximate estimates of profit / loss from the application of the algorithm tested within the framework of DVC. It should be noted that when developing the experiment of the second type, special attention should be paid to the issue of eliminating mutual influence between the modules of the distributed codec.

Evaluation of the interframe prediction algorithm without taking into account the peculiarities of the distributed video codec

To carry out the evaluation without taking into account the features of the distributed codec, existing methods of comparing time interpolation algorithms are used, for example, within the framework of the frame rate conversion task, which allow to evaluate the visual quality of interpolation regardless of how these algorithms are used in the DVC scheme.

The most common method of evaluating time interpolation algorithms is the following. Many test video sequences are formed and each sequence is thinned out, for example, by discarding every second frame. Next, a time interpolation algorithm is used to restore discarded frames to each pair of remaining adjacent frames. The original discarded frames are then compared with the interpolated one.

Graphs comparing frame-by-frame values of the PSNR criterion for all test sequences are shown in fig. 2. Average PSNR values calculated for all interpolated frames are summarized in Table 1.

Table 1. The average value of the PSNR criterion for intermediate frames

Sequence	Basic algorithm	The proposed algorithm
Coastguard	32:13	34:66
Football	22:84	23:96
Foreman	32:55	34:25
Hall	36:89	37:35
Soccer	25:13	27:66

From the given results, it is clear that the developed algorithm, shows a generally higher quality of interpolation than the basic algorithm. In addition, it should be noted that the amount of gain depends on the characteristics of the video sequence. In order to explain this conclusion, let's consider the concept of "complexity of movement". By the complexity of the movement, we will understand a qualitative characteristic that depends on the intensity and direction of movement of objects in the video sequence: the faster and more chaotically the objects move, the more complex the movement. We will sort the sequences according to this criterion, and also estimate for each sequence the gain from applying the developed algorithm for generating additional information using the BD-PSNR criterion, which allows us to estimate the difference between two "speed-distortion" curves [6]. The results of this analysis are shown in Table 2.

Table 2. Dependence of profit on the complexity of the movement

Sequence	**The complexity of the movement**	**The difference in the value of PSNR, dB**
Coastguard	2	2:53
Football	4	1:12
Foreman	3	1:7
Hall	1	0:46
Soccer	4	2:53

Analyzing the data in Table 2, we can conclude that the more complex the movement in the video sequence, the greater the benefit from the application of the developed algorithm for generating side information. The obtained result is expected, because on sequences with a relatively simple movement, the accuracy of time interpolation is quite high in many algorithms, including the number of errors in side information is relatively small. As the complexity of the movement increases, so does the number of errors. The obtained results show that the number of errors in the developed algorithm grows more slowly, compared to the algorithm implemented in the DISCOVER codec [9, 10]. This is explained by the fact that this algorithm takes into account the true movement model when searching for the optimal vector field better than the approach implemented in DISCOVER.

3. Evaluation of an interframe prediction algorithm using a distributed codec

When evaluating the algorithm of interframe prediction with the subdivided codec, it is necessary to correct the restrictions set in subsection 1, and the very fact that the side information generation module is in close interconnection with the other modules of the codec. In order to overcome this problem, it is recommended to use the following approach. A video codec is implemented, which follows the scheme described in [4], [5].

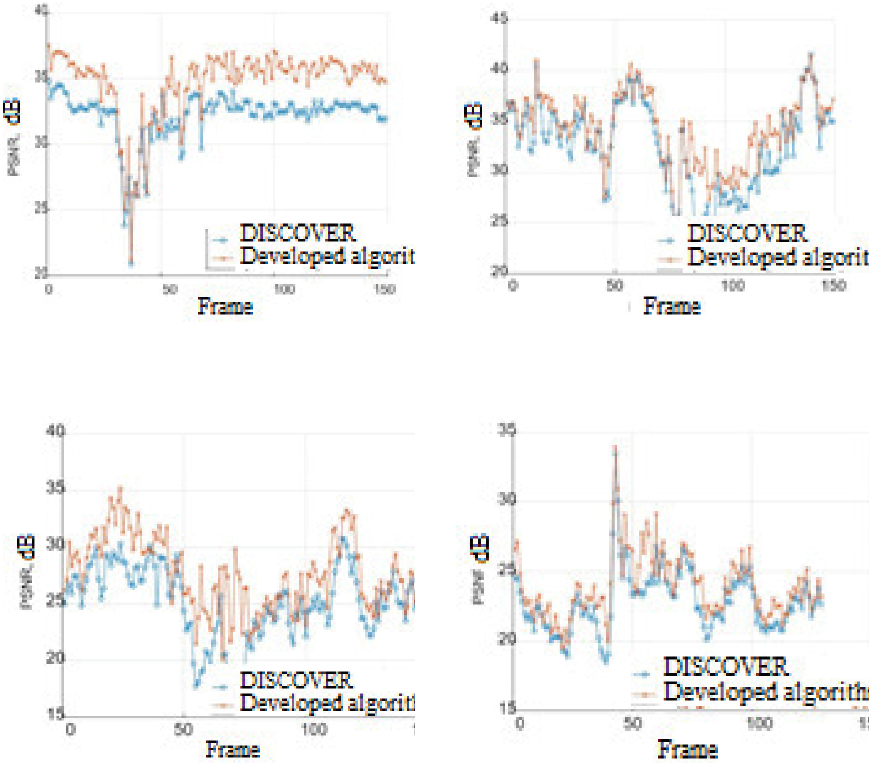


Figure 2. PSNR plots for interpolated frames

Reference frames are processed independently, for example according to the algorithm used in the DISCOVER codec. Interframe prediction of the intermediate frame is performed on the reconstructed reference frames. The prediction result is output to the output stream as a reconstructed intermediate frame. At the same time, interference-resistant coding for correcting errors on the side of information is not performed, i.e., intermediate frames are processed only on the decoder side and additional bits from the encoder are not needed. Thus, in a similar scheme, the bit costs for the transmission of intermediate frames are 0 bits, and approximating frames obtained in the process of generating side information are issued as restored frames. The scheme of the codec without feedback is shown in Figure 3. The total bit costs for compression of the entire sequence are determined only by the costs of storing information about reference frames. By changing the degree of compression of reference frames, "speed-distortion" curves are constructed, according to which a comparative assessment of various methods of time interpolation algorithms is carried out.

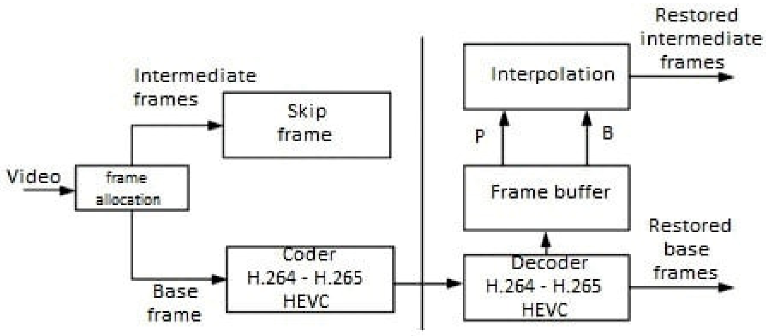


Figure 3. Structural diagram of a video codec for comparative evaluation of side information generation algorithms

The "velocity-distortion" curves constructed using the described method are shown in fig. 3. It can be seen that the developed interframe prediction algorithm wins over the basic algorithm on all test sequences. At the same time, as a rule, the more complex the movement in the video, the greater the significant advantage.

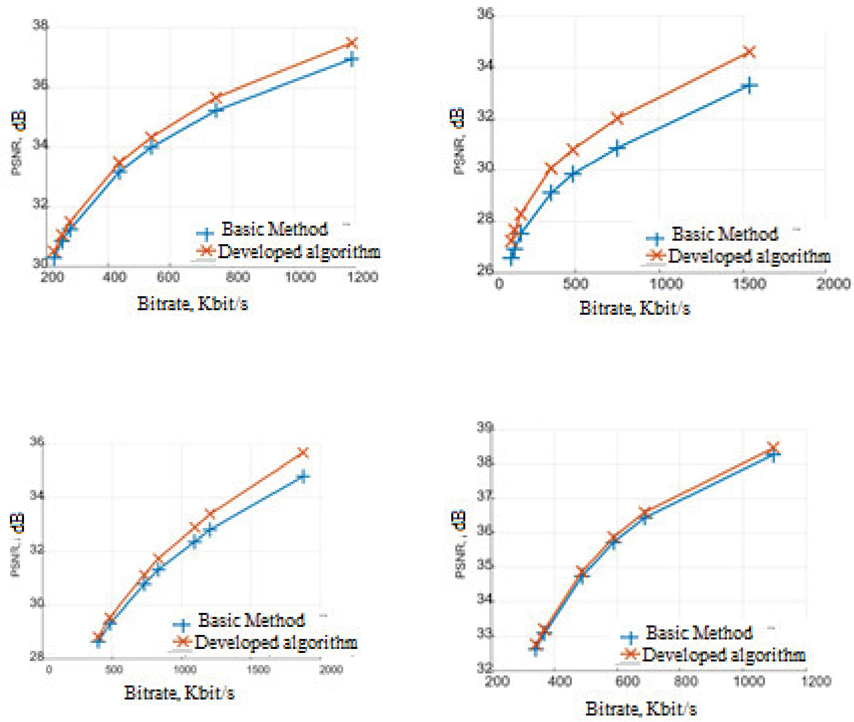


Figure 4. Results of comparison of additional information generation algorithms within the distributed codec

It should be noted that additional bits from the encoder side for the recovery of intermediate frames are not transmitted, the "distortion rate" curves for the simplified model without feedback can only be plotted for low and medium compression quality. Bugfixes will allow this graph to be extended into the high-quality region by increasing the bitrate.

4. Comparative analysis of the developed distributed video coding algorithm

This subsection presents the results of a comparison of the developed software model of a distributed video codec with existing compression algorithms:

1. H.264 codec working in Intra mode;
2. H.264 standard codec working in Inter mode;
3. H.264 standard codec working in Inter No Motion mode;
4. DISCOVER codec.

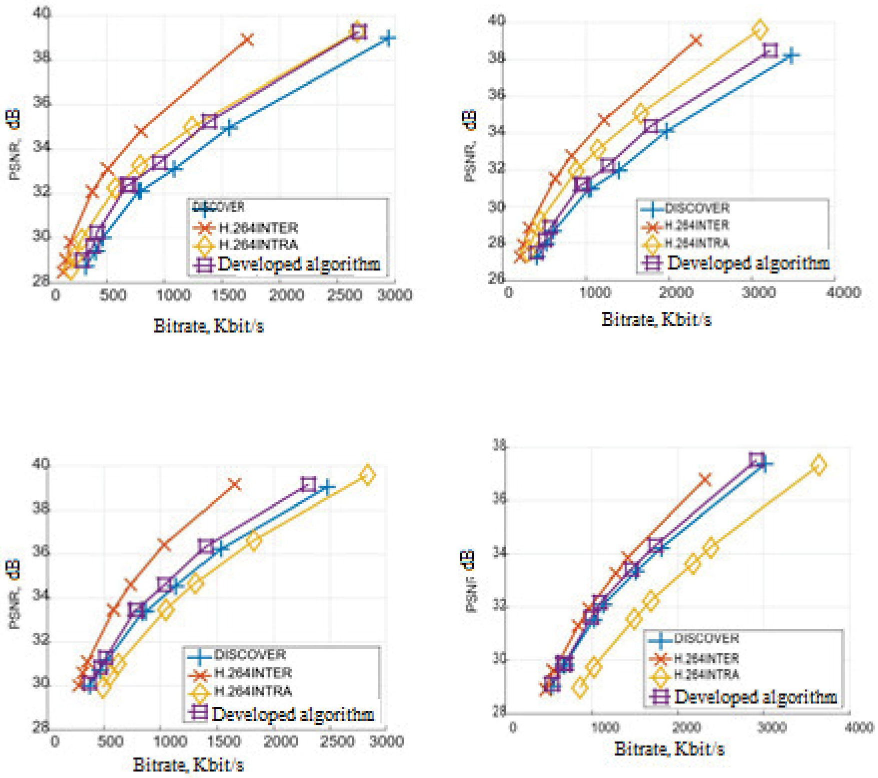
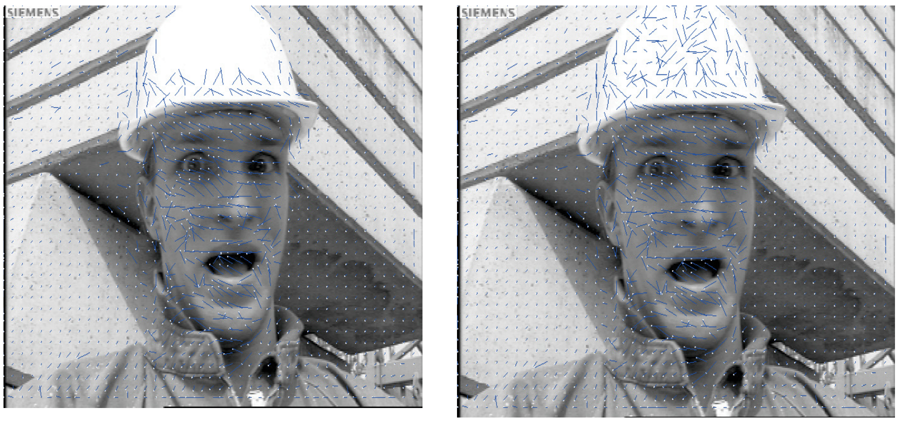


Figure 5. The results of matching with the "Sweetness-Creation" curve

In all tests, the reference implementation of JM version 9.5 was used as a codec. In H.264 Intra mode, all frames were processed as key frames. In other modes, the IBIB mode was used, that is, every second frame was processed as a key frame. It should be noted that in the H.264 Inter mode, interframe prediction and elimination of time redundancy is performed by the encoder, i.e., this curve can be considered as an example for joint encoding-decoding of dependent sources.

The results of the comparison with the "velocity-distortion" curve are shown in figure 5. On all sequences from the test set, the developed software model wins the DISCOVER codec on average. At the same time, both codecs lose on all sequences of the H.264 Inter codec. On sequences with high motion complexity (Football and Soccer), both Discover and the developed algorithm lose both H.264 Inter and H.264 Intra. However, it should be noted that at high quality for the Soccer sequence, the developed algorithm, unlike DISCOVER, shows a quality close to H.264 Intra. The results of the comparison of the developed software complex and the DISCOVER codec according to the BD-RATE criterion are shown in Table 3. It can be concluded that the use of the developed algorithms allows reducing bit costs by 4-16%, and the more complex the movement in the video sequence, the greater the gain.



the developed method DISCOVER codec

Figure 6. Frame of the video sequence "foreman" with highlighted motion vectors. on the left - the developed method, on the right - discover codec

Table 3. Comparison results of the implemented software complex and the DISCOVER codec according to the BD-RATE criterion

Sequence	**BD-Rate, %**
Coastguard	4:6
Football	12:4
Foreman	8:7
Hall	4:3
Soccer	15:8

This document presents the results of a comparative analysis of video information processing algorithms developed in the work within the framework of a compression system based on the principles of coding dependent sources. It is shown, that currently there is no open sale of a distributed codec, with the help of which it would be possible to conduct a comparative analysis of various algorithms for generating side decoder information and modeling a virtual channel. In this regard, based on the basic DISCOVER distributed coding model, a new codec software model was developed, comparable in terms of compression to the codec implemented as part of the DISCOVER project. The main features of this software model were given, as well as the tasks related to the implementation of the algorithms developed in sections 2 and 3 in this model were solved. Next, the method of performing a comparative analysis of algorithms was described, within which the main features that must be taken into account were indicated when comparing Also, a new method of comparative evaluation of additional decoder information generation algorithms was proposed, which uses a simplified codec model without feedback. It is shown that the developed algorithms allow to increase the degree of compression in comparison with the DISCOVER.

5. Conclusion

The main results of the article can be formulated as follows:

- a video codec software model was developed, based on the basic Discover distributed coding model;
- solved tasks related to the implementation of language algorithms developed in chapters 2 and 3 into the software model;
- proposed method of comparative evaluation of decoder side information generation algorithms;
- the benefit from the use of the algorithms developed in this work is demonstrated.
- ISCOVER codec by 16%.

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