Andrzej POPŁAWSKI
Uniwersytet Zielonogórski
Instytut Metrologii, Elektroniki i Informatyki

THE EFFECTIVENESS OF THE VIDEO SURVEILLANCE SYSTEMS IN CONDITIONS OF FREQUENT SCENE CHANGE

Monitoring and video surveillance systems are increasingly used in Internet of Things (IoT) devices. Various compression techniques are used, which contribute to the deterioration of image quality. This quality depends not only on the camera and compression technique used, but also on the content recorded by the camera. The article presents research on the coding efficiency used in video surveillance system in the conditions of frequent scene change.

EFEKTYWNOŚĆ SYSTEMU NADZORU WIZYJNEGO W WARUNKACH CZĘSTEJ ZMIANY SCENY

W urządzeniach Internetu rzeczy (IoT) coraz częściej stosowane są systemy monitorowania i nadzoru wizyjnego. Wykorzystuje się tu różne techniki kompresji, które przyczyniają się do pogorszenia jakości obrazów. Jakość ta zależy nie tylko od zastosowanej kamery i techniki kompresji, ale również od treści rejestrowanej przez kamerę. W artykule zostaną przedstawione badania efektywności kompresji wykorzystywanej w systemach nadzoru wizyjnego w warunkach częstej zmiany sceny.

1. INTRODUCTION

Effective use of many of today's services is possible thanks to use of compression that make storing and sending data easier. For the visual data, the amount of uncompressed information is very big. For many devices, large amounts of data often exceed their possibilities to storage or transfer data. Therefore, in many situations it would be impossible to use video without the use of data compression, for example in video surveillance systems. At present, most data transmitted over telecommunications networks are data containing moving images. It is estimated that the share of these data will systematically increase.

Various types of monitoring and video surveillance systems are increasingly used in Internet of Things (IoT) devices. It is obvious that compression is used to reduce the amount of data needed for transmission or collection [1, 2]. However, it reduces the quality of the images, which depends not only on the specific algorithm used, but also on the recorded content. As a rule, the more static the image, the more effective the compression. As the motion in the image captured by the camera increases, quality of the compressed image usually deteriorates. Meanwhile, in monitoring and video surveillance systems, a large amount of movement in front of the camera may be associated with the occurrence of an event. The recording of such an event is expected to be of good quality.

Techniques of video sequence compression have been used for many years and become more and more effective. Several coding standards, such as H.263, H.264/AVC [3, 4], commonly used in many fields, have been developed in the past. Recent work has resulted in a new, high-performance video compression technology: High Efficiency Video Coding – HEVC. This solution is covered by MPEG-H Part 2 (ISO/IEC 23008-2) of the International Organization for Standardization (ISO) and ITU-T Recommendation H.265 of the International Telecommunication Union (ITU) [5, 6].

HEVC is a significant achievement in the field of video compression. Studies show that using the HEVC technique instead of AVC allows for reducing the bit rate by half [7–9]. The new coding technique has significantly increased the adaptability (block size, prediction method, etc.) to the content of the encoded data. This has led to greater accuracy in the content prediction and, consequently, higher compression efficiency of video data [6, 9]. There are 35 inter frame predictors in HEVC encodings, and they can be used in blocks with the size of 4x4 to 64x64. This solution allows for efficient coding, but involves searching for a large number of possible cases, which translates into a high coding complexity [10]. A detailed description of solutions used in the HEVC technique can be found in [7, 8].

Usage of similarities that occur between adjacent frames is crucial in the compression of video sequences. Occurrence of these similarities is crucial to ensure high compression efficiency, as it allows for significant reduction of data redundancy in the processed frames. The closer the similarity of neighbouring frames, the more efficient video data can be compressed. In practice, the degree of similarity of neighbouring frames is not constant and varies depending on the content of the video material.

Most of today's used codecs take advantage of the fact that adjacent frames in a video are similar. It is obvious that from time to time in a video sequence there is a scene change. It means a certain change of the video sequence content, resulting in the absence of similarities between neighbouring frames. Such situation can take place e.g. when recording camera has been changed. In this situation similarities between adjacent frames are generally small. That is why an encoder can't encode video material as effectively as when scene change doesn't occur. As a matter of fact, in the real footage a scene change does not occur frequently. However, the faster camera movement is, the more dissimilar are adjacent frames. Also, quickly changing background in a movie e.g. rippling surface of water or flying confetti may cause significant differences between neighbouring frames. In such cases we can often talk about the scene change.

In the literature the issue of a scene change in a video sequence is mainly treated as a problem of detecting film shots. This is done for the purpose of segmentation and classification of video materials. The division of the sequence into shots is used, among others, for indexing and archiving videos [11–15]. Comparison of algorithms that detect scene change can be found in [16].

Another issue discussed in the literature is the change of the encoder behaviour when a scene change is detected. Amer et al. [17] showed a modified method of processing video sequences in case of a scene change. Xu et al. [18] proposed a new rate control algorithm based on variation of Group of Pictures (GOP) in scene variation conditions. Poobalasingam et al. [18] proposed a strategy for GOP selection in HEVC, as well as classification of the studied sequences, due to their dynamics, content and the occurrence of a scene change. The authors treat a scene change as the case where a sequence has more than one camera view and thus the scene changes. Sowmyayani et al. [20] presented an adaptive GOP structure with the new logic of frame comparison in H.264/AVC to achieve better quality and reduce bit rate based on scene change. Some works also deal with issues such as reducing encoding complexity [21, 22] or effective HEVC implementations [23].

The above mentioned sources mostly focus on improving coding efficiency of hybrid encoders. However, there is no work presenting the decrease in compression efficiency in the case of frequent scene change and the impact of coded content on the compression quality. It is known that the scene change in a sequence have an adverse influence on the compression efficiency. The question is how strong the influence is and what effect the content has on the deterioration of the encoded images quality.

This paper presents experimental results on HEVC video coder under simulated conditions of the scene change. Experiments were carried out using a representative group of video test sequences. The video sequences were modified to obtain simulated scene change at predetermined frequencies. Quality measurements were performed for the luminance component by calculating the mean value of the PSNR for all pictures in a given sequence.

2. METHODOLOGY OF THE EXPERIMENTS

The aim of the experimental research was to examine behaviour of the HEVC video codec in frequent scene change conditions. Occurrences of a scene change in video sequences imply a less effective analysis in the time domain. Such situation is resulting from a lack of similarity between adjacent frames on the border of the scene change. This in turn can cause a significant redundancy decrease in an input video sequence. In research on video codecs that are available in a literature, there are mostly used video sequences without scene change.

For the experiments, six test video sequences were taken [24]: Basket, City, Crew, Harbour, Ice and Soccer in format CIF 30Hz (352x288) and with a length of 6.4 seconds (192 images). The selected sequences are commonly used to assess effectiveness of the video sequence compression. They are characterized by variable dynamics both in the foreground and in the background.

The Basket sequence shows a basketball game, in the foreground there are players that are playing a game, the audience is in the background. The camera follows the ball, sometimes the background is almost motionless but from time to time the movement of the camera is dynamic. Generally, this video sequence is characterized by high dynamics of movements.

The City sequence shows a bird's eye view of the city. In the foreground there is one building, while the background shows other buildings. The dynamics of the sequence is comparatively small; the movement of the camera is smooth. In the sequence there are no motionless fragments.

The Crew sequence shows a group of several people dressed in the orange space suits. People are walking at the leisurely pace. The background of the sequence moves slightly at the beginning and quickly at the end. This change is associated with a change of the walking direction of the people in the sequence. The dynamics of the sequence is slightly larger then in the City sequence.

The Harbour sequence shows a view of a port in which sailboats are docked. The camera is mounted on a tripod; it performs only small movements, which can be caused by gusts of wind or due to low stiffness of the tripod. Majority of the background is the water surface in which the boats are sailing. The dynamics of the sequence is low.

The Ice sequence shows a view of ice rink, where a dozen or so people perform ice skating. The foreground is still, the ice ring is used by people, standing and quickly moving. In the sequence motionless and fast moving elements exist.

The Soccer sequence shows a view of sports ground, where some people play football. The camera follows the ball. Sometimes the background is almost motionless, but from time to time the movement of the camera is moving fast. In the sequence there are moments of both small and high dynamics of motion.

In the paper the Scene Change (SC) parameter is introduced. Its value determines how often a scene changes occur in an input video sequence. It was assumed that test video sequences will be used, for which the SC parameter will receive values: 32, 16, 8, 4, 2, 1. Accordingly, the least frequent scene change will take place every 32 images, the next one every 16 images, while the most frequent one after each image. Thus, for the value of the SC parameter equal to 1, every frame of a video sequence will be dissimilar to the next or previous frame in the video sequence. Furthermore, it was assumed that for the value of SC parameter equal to 0 the scene change doesn't occur. Video coding in this case will be performed with usage of the test video sequences without the scene change.

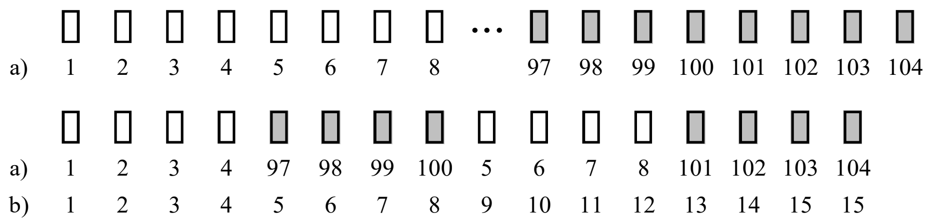

Fig. 1. Reordering scheme of frames in the sequence for SC parameter equal to four; a) image numbers of the original sequence, b) image numbers of the modified sequence
Rys. 1. Schemat zmiany kolejności obrazów w sekwencji dla parametru SC równego 4; a) numery obrazów sekwencji oryginalnej, b) numery obrazów sekwencji zmodyfikowanej

In the research it is important to properly choose the material for experiments. The content of analyzed images for a given sequence should be the same for each value of the SC parameter. That is why it was decided to use original test video sequences in which the order of images was changed. Test video sequences used in the research were modified in such a way as to contain the same contents regardless of assumed value of the SC parameter.

To simulate a scene change, the original test video sequence that consists of 192 pictures has been divided into two equal fragments. The first portion contained successive pictures in the sequence from the 1st one to the 96th, the second portion was successive pictures form the 97th one to the 192nd (Fig. 1). In the next step, pictures from the first and second portion were joined alternately. The number of successive combined pictures of each part depends on value of the SC parameter. For example, for a scene change every 4 pictures (SC=4), successive pictures from 1st to 4th were stored in the resulting sequence, then pictures from 97th to 100th, after them the 5th to the 8th, then the 101st to the 104th and so on. The successive pictures are taken from the original video sequence (Fig. 1). With such a method, every four pictures the simulated scene change occurs. Pictures 4th and 5th then 8th and 9th of the new sequence are dissimilar enough. We can thus say that the change of scene took place.

Such actions cause a nature of newly created sequence (dynamics, colours) is preserved. The new sequence was created with the same images, but only in different order of appearance. For each original test sequence six modified video test sequences were created for values of SC ={32, 16, 8, 4, 2, 1}. For example, based on the original test sequence Basket, the following test sequences were created: Basket32, Basket16, Basket08, Basket04, Basket02, Basket01 (numbers in names correspond to the value of the parameter SC). Total 36 modified test video sequences were created.

3. EXPERIMENTAL RESULTS

Commonly available HEVC reference software [25] has been used in the experiments. Random access encoding configuration was applied, as defined in [26]. Using this software, a series of experiments was done with the following encoding settings:

- profile – main,
- GOP Size – 8,
- Intra Period – 32,
- Search Range for motion estimation – ±64.

The tests were executed on the personal computer with Intel Core i7 2700K and 8GB RAM. To measure the quality, the PSNR (Peak Signal-to-Noise Ratio) was used:

$$PSNR = 10\log\frac{255^2 N^2}{\sum_i e_i^2}[dB], \qquad (1)$$

where 255 is the dynamic range of the signal, N is the number of pixels in the picture and e_i – difference between the i-th pixel of the original and processed images.

The measurements were performed for the luminance component by calculating the mean value of the PSNR for all the pictures in a given sequence. This method is widely applied by many researchers.

Table 1

Selected BR and ΔB values depending on SC parameter value and bitrate

Sequence name	BR_S	BR_O	ΔBR	ΔB_{32}	ΔB_{16}	ΔB_8	ΔB_4	ΔB_2	ΔB_1
Basket	256	270,81	14,81	0,04	-0,07	-0,03	0,30	-0,11	0,00
	512	526,89	14,89	0,17	0,17	-0,02	0,22	-0,16	-0,20
	768	783,27	15,27	-0,41	0,19	-0,40	-0,01	-0,58	0,10
	1024	1039,33	15,33	-0,15	-0,13	-0,31	-0,45	-1,39	1,44
City	256	271,00	15,00	-0,17	-0,11	-0,19	-0,29	-0,22	0,02
	512	527,00	15,00	0,10	0,00	0,08	-0,14	-0,04	0,94
	768	783,17	15,17	0,09	0,37	2,37	-0,03	0,01	2,13
	1024	1040,02	16,02	-0,70	-0,58	-0,63	-0,81	-0,98	2,51
Crew	256	270,91	14,91	-0,08	0,08	-0,01	-0,18	-0,20	0,24
	512	527,29	15,29	-0,49	-0,50	-0,09	-0,45	-0,54	0,55
	768	783,94	15,94	-0,93	-0,98	-0,37	-1,08	-1,13	0,27
	1024	1040,34	16,34	-1,53	-1,51	-1,29	-1,50	-1,51	0,53
Harbour	256	270,83	14,83	0,15	0,39	0,78	-0,11	-0,04	0,06
	512	528,27	16,27	-0,48	-0,74	-0,32	-1,33	-1,10	-0,97
	768	784,36	16,36	-0,05	0,03	-1,06	-1,41	-1,21	-0,80
	1024	1040,98	16,98	0,01	-0,39	0,04	-1,54	-1,40	-0,93
Ice	256	271,11	15,11	0,04	-0,05	-0,21	-0,20	0,31	0,22
	512	527,34	15,34	-0,19	-0,17	-0,16	-0,18	0,63	0,70
	768	783,80	15,80	0,23	0,23	0,18	0,25	0,78	0,85
	1024	1040,03	16,03	0,30	-0,25	0,01	-0,41	0,28	1,32
Soccer	256	270,70	14,70	0,24	0,46	0,34	0,08	-0,06	0,34
	512	526,90	14,90	0,09	0,07	0,21	-0,05	-0,05	0,47
	768	783,22	15,22	-0,16	-0,34	-0,27	-0,06	0,30	0,41
	1024	1038,97	14,97	0,34	0,15	1,83	0,30	0,30	0,75

The experiments consisted in encoding and then decoding test video sequences with twelve various assumed bitrates: 128, 196, 256, 384, 512, 640, 768, 896, 1024, 1152, 1280, 1408 kb/s. In total, 504 encoding and decoding operations (84 operations for each of the 6 video sequences tested) were performed. As a result, 504 encoded data streams were achieved (84 data streams for each of the video sequences tested). Then the streams were decoded and PSNR values calculated.

The actual bitrate values obtained from the experimental studies were higher than those assumed in the coder settings. In the paper, the difference in bitrate received and set, for SC=0 is denoted as delta Bitrate Received (ΔBR):

$$\Delta BR = BR_O - BR_S[kb/s], \tag{2}$$

where ΔBR is the difference between the bitrate obtained and set for SC=0, BR_O is the obtained value of bitrate at SC=0 and BR_S – set value of bitrate at SC=0.

The resulting values of ΔBR are in the range from 14,70kb/s to 18,03kb/s. The difference of the bitrate values for all tested sequences and the tested bitrates (expressed as ΔBR) were similar. Thus, the ΔBR changes do not affect the interpretation of the obtained results. The average value of ΔBR was 15.53 kb/s.

For the experiments made for the remaining SC values, the ΔB_X (delta bitrate for SC = x) was introduced. It determines the difference between the bitrate obtained for the SC parameter equal to x, where x={1,2,4,8,16,32} and the bitrate obtained for SC=0:

$$\Delta B_X = BR_X - BR_O[kb/s], \tag{3}$$

where ΔB_X is the difference between the bitrate obtained for the SC=x and the bitrate obtained for SC=0, BR_X is the obtained value of bitrate at SC=x, and BR_O – obtained value of bitrate at SC=0.

The values of ΔB_X for particular sequences and for different SC values are small, in most cases ΔB_X does not exceed ±1kb/s (Table 1). The average value of ΔB_X was –0.13 kb/s.

In further analysis of the results, only the real bitrate values, obtained during the experimental study were taken into account. The presented changes in the actual bitrate have no direct effect on the interpretation of the obtained results.

In the next step, a decoded sequence was compared to the original one, and the quality of the decoded sequence was measured. The Video Sequence PSNR Difference (VSPD) measure has been used for this purpose:

$$VSPD = PSNR_0 - PSNR_{SC}[dB], \tag{4}$$

where $PSNR_0$ is the PSNR value in the event of the absence of a scene change, and $PSNR_{SC}$ is the PSNR value in the event of the presence of a scene change.

This measure defines the difference between the PSNR value in the absence of a scene change and the PSNR value in the presence of a scene change.

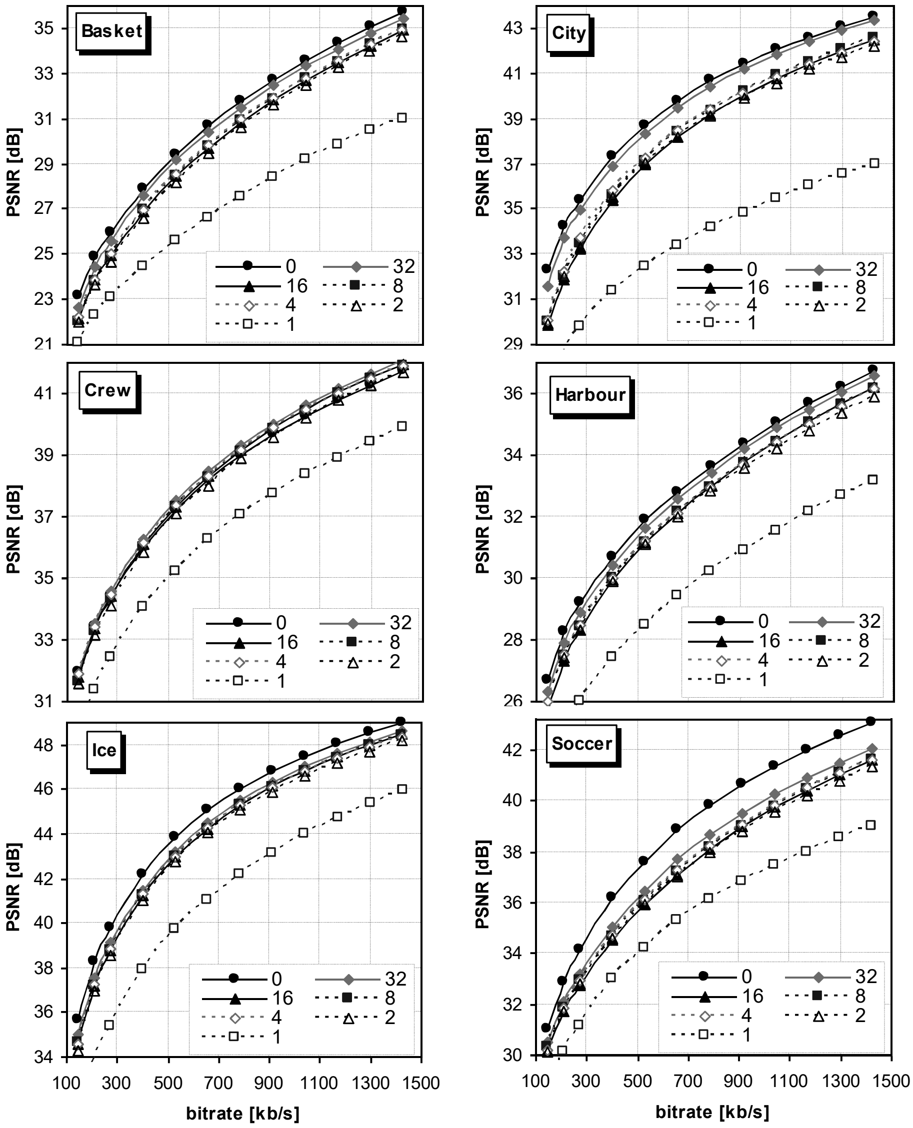

Fig. 2. The rate distortion curves for the testing sequences for SC parameter equal to 0, 32, 16, 8, 4, 2, 1

Rys. 2. Efektywność kodowania testowych sekwencji dla parametru SC równego 0, 32, 16, 8, 4, 2, 1

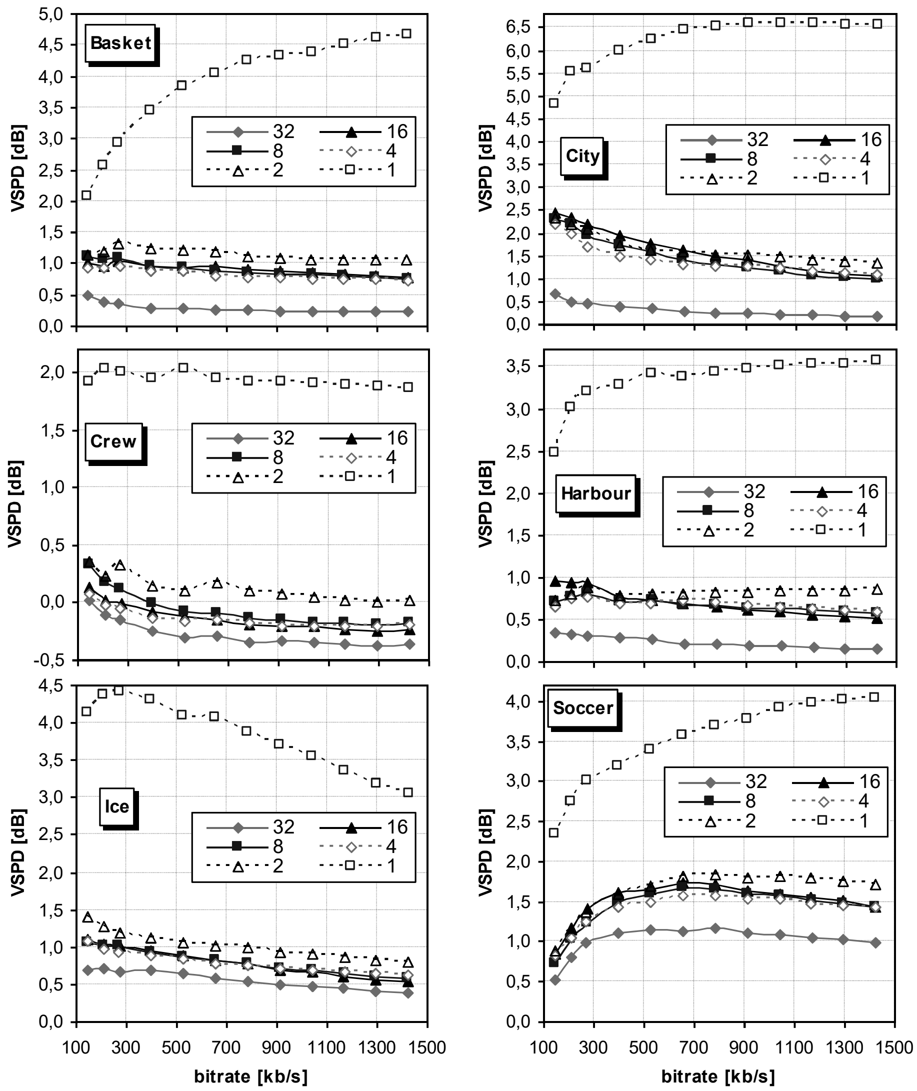

Fig. 3. The VSPD values for the testing sequences for SC parameter equal to: 32, 16, 8, 4, 2, 1
Rys. 3. Wartości VSPD dla testowych sekwencji dla parametru SC równego: 32, 16, 8, 4, 2, 1

Fig. 2 shows the obtained values of the PSNR for particular SC values, for the tested video sequences and bitrates from 128 kb/s to 1408 kb/s. Fig 3 shows the obtained values of the VSPD (PSNR decrease) for increasing frequency of scene change from 32 images to 1 image. The biggest drop in the PSNR value was recorded for the City sequence – on average 2.13dB, form 0.18dB for SC=32 and bitrate equal to 1408kb/s, to 6.60dB for SC=1 and bitrate equal to

1024kb/s. Whereas the smallest drop in the PSNR value was noted for the Crew sequence – on average 0.25dB, most of 2.03dB for SC=1 and bitrate equal to 196kb/s. For the remaining video sequences the maximum decreases of the PSNR values were:

- 4.67dB at 1408kb/s for the Basket sequence, on average 1.31dB;
- 3.57dB at 1408kb/s for the Harbour sequence, on average 1.07dB;
- 4.41dB at 256kb/s for the Ice sequence, on average 1.31dB;
- 4.04dB at 1408kb/s for the Soccer sequence, on average 1.73dB.

For all tested video sequences the VSPD values are the greater the more often the scene change occurs. The drop in the PSNR value is bigger for sequences with smooth movement and low dynamic, e.g. City – (Fig. 3) in contrast to sequences with high dynamic, e.g. Crew, Harbour.

It is due the fact that for video sequences with high dynamic, differences between successive frames are smaller then in video sequences with lower amount of motion. Accordingly, the occurrence of a scene change in sequences with high dynamic cause a smaller decrease in PSNR compared to the sequences with less dynamics.

It is noteworthy that for the Crew sequence for almost all bitrates and for SC equal to 32, 16, 8 and 4 there was observed negative value of the VSPD (Fig. 3). This means that in these cases, occurrence of scene change causes an increase the PSNR value compared to a situation when there is no scene change.

Another noteworthy fact is the much greater value of VSPD for SC=1 compared to other SC values tested. The VSPD is from 2 to 4 times higher (average 3.4 times) for SC=1 compared to CS=2. On the other hand, the VSPD values for SC=4 in comparison to SC=2 increase by 1.25 times.

For all tested sequences, the lowest value of VSPD was obtained for SC=32. For SC equal to 16, 8 and 4, the VSPD coefficient varies in a relatively small range. VSPD slightly increases with SC=2, and very strongly increases with SC=1. Of course, in practice changing the content of a video sequence, which means changing the scene every one picture, may occur very rarely. But this can be happen, for example, in the case of the dynamic camera movement or in video with large amount of moving objects (e.g. confetti or snowflakes).

The presented results also show that in most cases the change of bitrate for the given SC value does not cause a significant change of the VSPD value. This situation occurs especially at higher bitrates. The VSPD value remains at a similar level (Fig. 3). Only in few cases the value of the VSPD depends clearly on the bitrate. Such situations are mainly for SC=1 and sequences: Basket, City, Harbour, Ice, and Soccer (Fig 3). It follows that the transmission speed has a relatively small influence on the VSPD value at particular values of the SC.

4. CONCLUSION

In the paper, results of experimental research on HEVC video codec under the simulated conditions of the scene change are presented. Video sequences were modified to obtain simulated scene changes at predetermined frequencies equal to: 1, 2, 4, 8, 16 and 32 pictures. The selected sequences are commonly used to assess the effectiveness of video sequence compression. The results obtained in case of the scene change presence were compared to the results with no scene change. The research shows that a scene change in video sequences leads to drop in the PSNR value. The more frequent the scene change, the bigger the drop of the PSNR is. Moreover, the less dynamic video sequence, the greater decrease of the PSNR value is. For sequences with high dynamics, average drops of the PSNR values were almost two times smaller than the drop of the PSNR values for sequences with low dynamics. The exception is the Crew sequence, where negative VSPD values were recorded.

In monitoring and video surveillance systems used in Internet of Things (IoT) devices, video recording often carries significant value only when a large amount of motion occurs. This is a situation when some kind of the sudden event occurs. A significant amount of motion causes negative effects, as in the case of changing the scene described in the article. Research indicates that in such a situation, the quality of the recording may significantly deteriorate. To counteract this, solutions increasing the transmission speed when there is a significant amount of motion in the recordings should be considered. Such an approach makes possible compensation for the temporary quality loss caused by temporarily increasing the transmission speed of recorded images.

The presented results may therefore be helpful in configuring the coder operating parameters in IoT devices. Increasing the transmission speed when a large amount of motion is detected may increase the readability of camera records. If the link used does not allow for the transmission of the increased amount of data, the solution may be to store the recorded material locally on the recording device.

Although the presented research results will not directly contribute to increasing the efficiency of the coding process itself, they can be used to introduce certain modifications to the encoder settings in order to better adapt it to the specificity of IoT devices.

REFERENCES

1. R. Pereira R., Pereira E. G.: Video Streaming Considerations for Internet of Things, International Conference on Future Internet of Things and Cloud, Barcelona, 2014.
2. Kokkonis, G., Psannis, K.E., Roumeliotis, M. et al.: Real-time wireless multisensory smart surveillance with 3D-HEVC streams for internet-of-things (IoT). The Journal of Supercomputing 73, 2017.
3. ITU-T Rec. H.263, Video Coding for Low Bitrate Communication, 2005.
4. ISO/IEC 14496-10, International Standard, Generic Coding of Audio-Visual Objects, Part 10: advanced Video Coding, 6th ed., 2010, take ITU-T Rec. H.264, Edition 5.0 (version 11), 2010.
5. ISO/IEC International Standard 23008-2: ITU-T Recommendation H.265: April 2015, High efficiency video coding, 2015.
6. Sullivan, G.J., Ohm, J.-R., Han, W.-J., Wiegand, T.: Overview of the High Efficiency Video Coding (HEVC) Standard. IEEE Transactions on Circuits and Systems for Video Technology, 22 (12), pp. 1649–1668, 2012.
7. Sze, V., Budagavi M., Sullivan, G.J.: High Efficiency Video Coding (HEVC): Algorithms and Architectures, Springer, 2015.
8. Wien M.: High Efficiency Video Coding: Coding Tools and Specification, Springer, 2015.
9. Ohm, J.R., Sullivan, G.J., Schwarz, H., Tan, T.K., Wiegand, T.: Comparison of the coding efficiency of video coding standards – Including High Efficiency Video Coding (HEVC). IEEE Transactions on Circuits and Systems for Video Technology, no. 22(12), pp. 1669–1684, 2012.
10. Bossen F., Bross B., Suhring K., Flynn D.: 2012. HEVC Complexity and Implementation Analysis. IEEE Transactions on Circuits and Systems for Video Technology, no. 22 (12), pp. 1685–1696, 2012.
11. Huang, C. L., Liao, B. Y.: A robust scene-change detection method for video segmentation. IEEE Transactions on Circuits and Systems for Video Technology, vol. 11, no. 12, pp. 1281–1288, 2001.
12. Yi, X., Ling, N.: Fast pixel-based video scene change detection. IEEE International Symposium on Circuits and Systems, pp. 3443–3446, 2005.
13. Li, Z., Liu, G.: Video scene analysis in 3D wavelet transform domain. Multimedia Tools and Applications, vol. 56, no. 3, pp. 419–437, 2012.
14. Eom, Y., Park, S., Yoo, S., Choi, J. S., Cho, S.: An analysis of scene change detection in HEVC bitstream. In Semantic Computing (ICSC), IEEE International Conference on, pp. 470-474, 2015.

15. Eom, Y., Park, S., Chung, C. W.: An analysis of Scene Change Detection using HEVC coding additional information. Journal of Broadcast Engineering, no. 20(6), pp. 871-879, 2015.
16. Reddy, B., Jadhav, A.: Comparison of scene change detection algorithms for videos. In Advanced Computing & Communication Technologies (ACCT), Fifth International Conference on, pp. 84-89, 2015.
17. Amer, H., Yang, E. H.: Scene-based low delay HEVC encoding framework based on transparent composite modeling. In Image Processing (ICIP), IEEE International Conference on, pp. 809-813, 2016.
18. Xu, S., Yu, M., Fang, S., Peng, Z., Wang, X., & Jiang, G.: New rate control optimization algorithm for HEVC aiming at discontinuous scene. WSEAS Transactions on computers, no. 14, pp. 598-606, 2015.
19. Poobalasingam, V., Izquierdo, E.: Steadiness analysis for optimal GOP size selection in HEVC. In Image Processing (ICIP), 2016 IEEE International Conference on, pp. 799-803, 2016.
20. Sowmyayani, S., Rani, J., Arockia, P.: Adaptive GOP structure to H.264/AVC based on Scene change. ICTACT Journal on Image & Video Processing, no. 5(1), 2014.
21. Wang, S., Luo, F., Ma, S., Zhang, X., Wang, S., Zhao, D., Gao, W.: Low complexity encoder optimization for HEVC. Journal of Visual Communication and Image Representation, no. 35, pp. 120-131, 2016.
22. Fernández, D. G., Del Barrio, A. A., Botella, G., García, C., Meyer-Baese, U., Meyer-Baese, A. (2016, May). HEVC optimizations for medical environments. In SPIE Commercial+ Scientific Sensing and Imaging, International Society for Optics and Photonics, pp. 98710B-98710B, 2016.
23. Ohm, J. R., Sullivan, G. J., Sze, V., Wiegand, T., Budagavi, M.: Introduction to the Special Issue on HEVC Extensions and Efficient HEVC Implementations. IEEE Transactions on Circuits and Systems for Video Technology, 26(1), pp. 1-3, 2016.
24. Test video sequences [Online] ftp://ftp.tnt.uni-hannover.de/testsequences/
25. HEVC test model reference software available online: https://hevc.hhi.fraunhofer.de/
26. Bossen, F.: Common test conditions and software reference configurations, Joint Collaborative Team on Video Coding (JCT-VC) of ITUT SG16 WP3 and ISO/IEC JTC1/SC29/WG11, Doc. JCTVC-J1100, Stockholm, Sweden, 2012.