# Comparative Analysis of In-Loop Filtering within Emerging High Efficient Video Coding (HEVC) Standard

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***Abstract*—High definition videos (HDVs) have captured the current market of video coding and media. Keeping in view of that Joint Collaborative Team on Video Coding (JCTVC) developed a video coding standard known as High Efficiency Video Coding (HEVC). It is a state-of-the-art video coding tool but its performance suffers from blocking artifacts to achieve high compression ratio. HEVC is thus equipped with the in-loop filter for suppressing of blocking artifacts. This paper describes the comparative analysis of HEVC in-loop filter which comprises of de-blocking and sample adaptive offset (SAO) filters. Various high definition video sequences of 1080p and 720p are used for comparing results of with or without in-loop filtering. Simulation results that in-loop filter can suppress blocking artifacts effectively without losing subjectivity of video.**

***Index Terms*—high definition video, HEVC, in-loop filtering, de-blocking filter, performance analysis**

## I. Introduction

The ongoing demand for efficient video coding to achieve low bit rate and high video quality is growing due to increasing popularity of high definition TV, the delivery of video on mobile devices, camcorders, digital cinema, home cinema, internet streaming, medical imaging, mobile streaming, broadcast and communications, video-conferencing, video-phone, tele-presence, remote video surveillance, wireless display and other multimedia applications [1].

Spatial redundancy is the numerical similarity and/or, near-similarity of adjacent pixel values within video frames. This redundancy can be exploited to correctly predict the values of adjacent pixels, and hence lessen the amount of data to be encoded. Indeed most of the major video encoding standards like MPEG-4, H.264 and HEVC perform video frame compression by taking advantage of this redundancy. The method employed by these encoding standards is known as 'Block-Based Discrete Cosine transform (BDCT)' encoding schemes [2]. As the name suggests, each frame is divided into blocks, and each block is then transformed using a Discrete Cosine Transform (DCT). The DCT is followed by Quantization and Entropy Coding. These operations results in a compressed bit sequence/stream.

The transformed coefficients are first divided into quantization levels, and then rounded off to the nearest integers. To get a higher compression ratio; all the Higher-order transform coefficients are coarsely quantized (usually to zero). As a result, we have a loss in correlation between adjacent blocks, which in turn gives rise to a phenomenon called blocking artifacts. Blocking artifacts is a distortion that appears in compressed video frames as abnormally large pixel blocks. This problem can be further compounded by Motion Compensation, a technique that predicts a frame in a video using previous and/or future frames.

To improve the visual quality of the frames, 'De-blocking filters' are applied to suppress the blocking artifacts. There are two main approaches to the application of De-blocking filters, post filter and in-loop filter. In post filtering the filtering is done by making use of the decoded parameters, after the decoding process. The post filter operates on display buffer outside the coding loop, and its use is strictly optional as it is not a normative part of the video coding standards. The in-loop filter on the other hand is employed within the coding loop and is applied to the reconstructed frames inside the encoder and decoder. The types of in-loop filters employed in various coding standards are different. For example, H.263 employed no filtering at all, while MPEG-4 employed optional in-loop filtering and post processing filtering. H.264 on the other hand employed

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in-loop filter and post-Filter processing, though not in its complete entirety. HEVC in-loop filtering involves De-Blocking Filtering (DBF) and Sample Adaptive Offset Filtering (SAO).

High Efficiency Video Coding (HEVC) which is a relatively incipient but highly efficient coding standard was jointly developed by Joint Collaborative Team on Video Coding (JCTVC), a consortium of ISO/IEC Moving Picture Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG). Performance analysis of HEVC has shown it to be a highly superior coding standard in comparison to its predecessor H. 264/AVC standard. For High Definition Videos of similar quality it can offer an approximately 50% bit rate improvement as compared to H. 264/AVC standard [3]. On the other hand, in applications where minimizing bandwidth is not the highest priority HEVC can be used to significantly improve video quality at the same bit-rate as MPEG AVC. HEVC employs in-loop filter for suppression of blocking artifacts. The in-loop filter consists of a De-blocking and Sample Adaptive Offset (SAO) filter. This paper describes the performance analysis of HEVC in-loop filter for various high definition video sequences.

## II. HEVC In-Loop Filter

In order to reduce or suppress the blocking artifacts, a pair of filters called De-Blocking Filter (DBF) and Sample Adaptive Offset Filter (SAO) is employed in the In-loop filter block of HEVC. The input of In-loop filter is fed into the DBF block and then passed through the SAO filter as shown in Fig. 1:

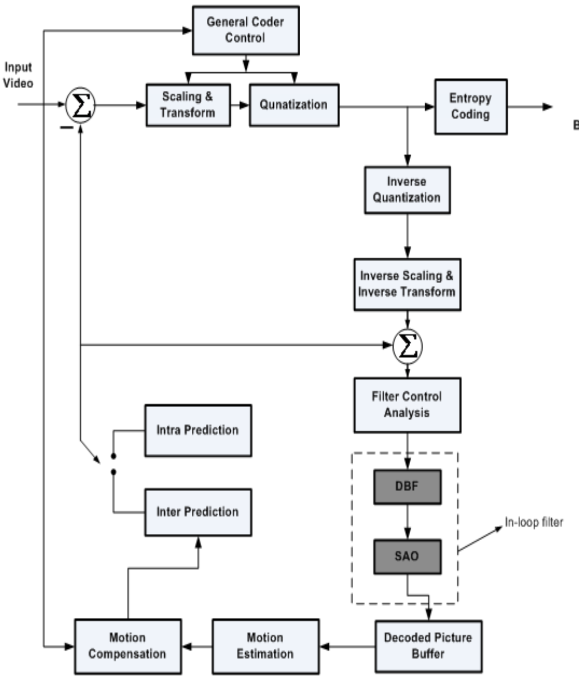


Figure 1. In-loop filter in HEVC block diagram

After removing the blocking artifacts the output from In-loop filter is forward to the next blocks. The detailed explanation is described as follows:

### A. *De-Blocking Filter (DBF)*

Though the De-blocking Filter is less complex than the filters used in the previous standards, yet it can still achieve a better subjective video quality, at half the bit-rate. The DBF of HEVC also has a better supportability for parallel processing. The main reason behind the appearance of blocking artifacts across the block boundary in the video frames is the misalignment of samples. This phenomenon is illustrated in the Fig. 2 in which $a_0 - a_3$ and $b_0 - b_3$ denotes the samples in A and B blocks, respectively.

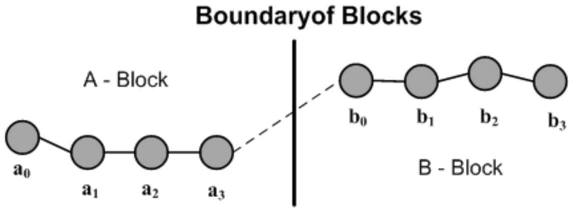


Figure 2. Samples misalignment phenomenon across block boundary

In HEVC the video frame is divided into sample blocks of 64×64 blocks called a Larger Coding Unit (LCU). These 64×64 are further divided into a smaller 32×32 Coding Unit (CU). The CU is further divided into a 16×16 block called Prediction Unit (PU). The PU is further divided into 8×8 block called Transform Unit (TU). A block size of 8×8 is used for filtering in HEVC, while H.264 standard used a block size of 4×4 sample blocks [4]-[6].

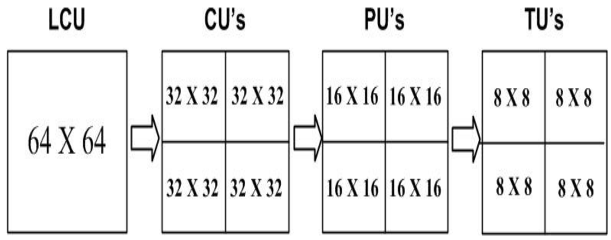


Figure 3. Partitioning of 64 by 64 LCU into CUs, Pus and TYs

To determine the type of filter to be used the boundary strength (bS) parameter is analyzed in HEVC. The boundary strength parameter has three possible values: 0, 1 and 2.

Following conditions must be met to apply the filtering on the sample blocks:

$$bS > 0 \tag{1}$$

$$(|\, a_{2,0} - 2 * a_{1,0} + a_{0,0}\, | + |a_{2,3} - 2 * a_{1,3} + a_{0,3}| + |b_{2,0} -* b_{1,0} + b_{0,0}\, | + |\, b_{2,3} - 2 * b_{1,3} + b_{0,3}| > \beta \tag{2}$$

where, a and b are the samples from first and fourth row of 8×8 sample grid boundary, which is illustrated in Fig. 3. The parameter β relates to the Quantization Parameter (QP). β is given in the standard and its value is chosen accordingly [7] .

In Fig. 3, horizontal filtering is first done on vertical boundaries, which is then followed by vertical filtering on the horizontal boundaries. After the filtering decision, another condition is checked to determine the type of filter that needs to be applied.

***If*** $( \; |a_{2,i} - 2*a_{2,i} + a_{0,i}| + |b_{2,i} - 2*b_{1,i} + b_{0,i}| > \beta/8 \;\&\&\; |a_{3,i} - a_{0,i}| + |b_{3,i} - 2*b_{1,i} + b_{0,i}| > \beta/8 \;\&\&\; |a_{3,i} - a_{0,i}| > 2.5*t_c)$

*Apply Strong Filtering;*

***Else***

*Apply Normal Filtering;*

where, $t_c$ is the threshold parameter and its value depends on the Quantization Parameter (QP). If the above '***If***' statement is true, a Strong Filtering is applied and three samples on each side of the boundaries are modified. In case the '***If***' condition is not true, Normal Filtering is applied and only two samples across each side are modified. Chroma filtering is sometimes also applied in case of Strong filtering. The modifications in samples are illustrated in Fig. 4,

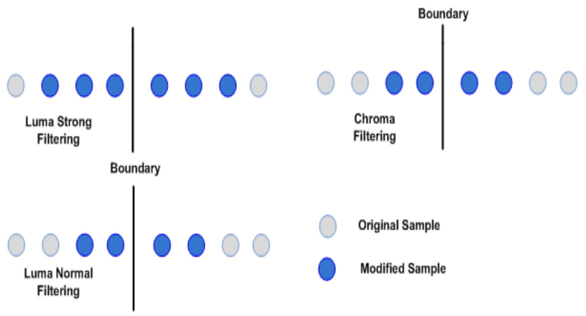


Figure 4. Samples modification in luma and chroma filtering

### B. *Sample Adaptive Offset Filter (SAO)*

SAO filter is the novelty in the in-loop filter design for HEVC standard. Output samples from DBF are given to SAO which assigns them particular offset by dividing them into categories. The offset assigned are of two types named as: Band Offset (BO) and Edge Offset (EO) depending on whether the 1-D classification has been done or band division has been used [7], [8].

## III. Simulation Results & Analysis

We have uses various test sequences in our experimental setup and then compare their results. These HD test sequences are taken from different resolutions of 720p and 1080p. We have selected a lot from which we can depict encoding process for videos of different speeds. The HEVC reference software (HM-9.2) is used to perform simulations and also for the results verifications.

This reference software was made available by Collaborative Team on Video Coding (JCT-VC) regrouping experts so that it can provide a reference implementation of the HEVC standard being developed by ITU-T SG 16 and ISO/IEC SC29 WG11. One of the main goals of the reference software is to provide a basis upon which to conduct experiments in order to determine which coding tools provide desired coding performance [10].

The test sequences taken in 720p resolution are STOCKHOLM, FOUR PEOPLE and DUCKS TAKEOFF while sequences taken in 1080p resolutions are RIVER BED, RUSH HOUR and TRACTOR. At the frame rate of 30 fps, 50 frames of each test sequence is encoded. These frames are encoded firstly by enabling in-loop filtering and then disabling the same for a conclusive comparison.

The comparison of with and without In-loop filter of all the 720p and 1080p test sequences is shown below in Table I. Where different test sequences are names and then their parametric comparison has been presented in the respective columns.

TABLE I: Y-PSNR COMPARISON TABLE

| **Test Sequence** | **QP** | **Y-PSNR comparison** | | |
|---|---|---|---|---|
| | | **With Filter (dB)** | **Without Filter (dB)** | **Difference (dB)** |
| **River_Bed (1920×1080)** | 25 | 37.5760 | 37.5553 | + 0.0207 |
| | 30 | 34.1769 | 34.1724 | + 0.0045 |
| | 35 | 31.1547 | 31.1511 | + 0.0036 |
| | 40 | 28.4421 | 28.4367 | + 0.0054 |
| **Rush_Hour (1920×1080)** | 25 | 41.3659 | 41.3273 | + 0.0386 |
| | 30 | 39.5677 | 39.5318 | + 0.0359 |
| | 35 | 37.4707 | 37.4045 | + 0.0662 |
| | 40 | 35.2177 | 35.1102 | + 0.1075 |
| **Tractor (1920×1080)** | 25 | 39.2338 | 39.2327 | + 0.0011 |
| | 30 | 36.7478 | 36.7015 | + 0.0463 |
| | 35 | 34.2383 | 34.1936 | + 0.0447 |
| | 40 | 31.6637 | 31.6471 | + 0.0166 |
| **Stolkholm (1280×720)** | 25 | 35.0603 | 34.9338 | + 0.1292 |
| | 30 | 31.3264 | 31.2049 | + 0.1215 |
| | 35 | 27.8006 | 27.7400 | + 0.0606 |
| | 40 | 24.9976 | 24.9736 | + 0.0240 |
| **Four_People (1280×720)** | 25 | 42.2759 | 42.3754 | +0.0995 |
| | 30 | 40.2455 | 40.3632 | +0.1177 |
| | 35 | 37.7356 | 37.8745 | +0.1389 |
| | 40 | 34.9069 | 35.0159 | +0.1090 |
| **Duck_Takeoff (1280×720)** | 25 | 36.5679 | 36.6915 | +0.1236 |
| | 30 | 33.9405 | 34.0289 | +0.0884 |
| | 35 | 31.2323 | 31.3123 | +0.080 |
| | 40 | 28.8306 | 28.8419 | +0.0113 |

Quantization parameters used for encoding are started from 25 and with the increment of 5 reached to 40 in three stages. This can be seen from the table that by enabling the filter there is a slight Peak Signal to Noise Ratio (PSNR) improvement from disabled filter encoding as shown by the positive (+) sign in the difference column. The blocking artifacts are thus suppressed by the help of In-loop filter. Fast moving frames are usually suppressed more on objects boundaries by de-blocking filter.

## IV. Conclusion

In this paper, comparative analysis of the In-loop filter is given with the help of reference software (RM – 9.2). The HD test sequences of 720p and 1080p resolution are taken for the simulations. Experimental results depict that by enabling the In-loop filter we can get good video

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quality with slightly higher PSNR. This is due to the fact that de-blocking filter suppresses the blocking artifacts.

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## REFERENCES

[1] ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11, "High efficiency video coding (HEVC) text specification draft 10 (for FDIS & Last Call)," JCTVC-L1003-v34, 12th Meeting, Geneva, pp. 14–23, 2013.

[2] G. Raja, *Optimized Low Bit Rate Video Coding: Algorithms for Suppression of Blocking Artifacts*, LAP Lambert Academic Publishing, Germany, 2011.

[3] G. Raja and M. Javed Mirza, "Performance Comparison of Advanced Video Coding H.264 Standard with Baseline H.263 and H.263+ Standards," in *Proc. 4th IEEE International Symposium on Communications & Information Technologies*, Sapporo, Japan, pp. 743-746, Oct. 26-29, 2004.

[4] G. J. Sullivan, J. R. Ohm, W. J. Han, and T. Wiegand, "Overview of the high efficiency video coding (HEVC) standard," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 22, no. 12, pp. 1649–1668, December 2012.

[5] H. Koumaras, M. Kourtis, and M. Drakoulis, "Benchmarking the encoding efficiency of H.265/HEVC and H.264/AVC," in *Future Network &Mobile Summit (FutureNetw)*, Berlin, Germany, 2012, pp. 1-7.

[6] J. Vanne, M. Viitanen, T. D. Hamalainen, and A. Hallapuro, "Comparative rate-distortion-complexity analysis of HEVC and AVC video codecs" *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 22, no. 12, pp. 1885–1898, December 2012.

[7] A. Norkin, G. Bjontegaard, A. Fuldseth, M. Narroschke, *et al.*, "HEVC deblocking filter," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 22, no. 12, pp. 1746–1754, December 2012.

[8] C. M. Fu, E. Alshina, A. Alshin, Y. W. Huang, C. Y. Chen, and C. Y. Tsai, "Sample adaptive offset in the HEVC standard," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 22, no. 12, pp. 1755–1764, December 2012.

[9] C. M. Fu, C. Y. Chen, Y. W. Huang, and S. Lei, "Sample adaptive offset for HEVC Multimedia Signal Processing (MMSP)," in *Proc. IEEE 13th International Workshop*, Hangzhou, China, 2011, pp. 1-5.

[10] F. Bossen, *et al.*, "HM software manual," *Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11*, January, 2013.

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