**Abstract:**

In the Statistical Collection part of the SAO(Sample Adaptive Offset) filter, It uses 48 offset bands (32 band offset + 16 edge offset). In general, each sampled pixel is processed on all the 48 offset bands. In the purposed system, it uses an additional filter which allows the sampled pixel to process on 8 offset bands only. The additional filter is designed based on the gray level of sampled pixel which reduces the computation on band offset determination.

**History of video codec:**

At the beginning video was stored as an analog signal on magnetic tape.When the compact disc came onto the market as a digital substitute for analog audio, it became possible to store and distribute video in digital form as well. A technique is needed to develop for the reduction of the amount of data used to display the raw video because of the large memory and bandwidth needed to store and transmit raw video. Then, engineers and mathematicians have tried to develop a number of solutions to achieve this goal of compressing the digital video content for better compression technique.

Discrete cosine transform(DCT) a new compression was introduced by the mathematicians: Nasir Ahmed, T. Natarajan and K. R. Rao. In the late 1980s, number of companies and organizations tried to use the Discrete Cosine Transform (DCT) a new lossy compression technique for video encoding and decoding, which leads to construct the new video coding standard called the H.261. It is the first practical/consumer video coding standard for video compression, developed by many organisations, including Hitachi, NTT, Toshiba and so on. After this, DCT (Discrete Cosine Transform) compression was considered to be a best algorithm for video coding.

MPEG was the familiar compression standard that was used by the codecs. In 1991, Motion Picture Expert Group(MPEG) evolved MPEG-1 to compress VHS-quality video. Later it was inherited by MPEG-2/H.262 in the year of 1994, developed by Sony, Thomson and Mitsubishi Electric. MPEG-2 was accepted as the standard video compression for DVD and Standard digital television. Then in the year of 1999, companies mainly Hitachi, Mitsubishi Electric and Panasonic developed MPEG-4/H.263, which was a great advancement for video compression technology.

H.264/MPEG-4 AVC was predominant video coding format, from 2016 to till date, developed in 2003 by Godo Kaisha IP Bridge, Panasonic and LG Electronics. H.264 is the main video encoding standard for Blu-ray Discs, and is widely used by streaming internet services such as YouTube, Netflix, Vimeo, and iTunes Store. web software such as Adobe Flash Player and various HDTV broadcasts over satellite and terrestrial television.

HEVC (H.265) has been take the place of AVC, developed in 2013 with the majority of patents belonging to Samsung Electronics, GE, NTT and JVC Kenwood.

**H.264:**

H.264 was formed by Motion Picture Expert Group (MPEG) in the year of 2003. H.264 also called as MPEG-4 part-10, working based on Block Oriented motion compensation based.Block Oriented Motion compensation can be done by doing motion compensation on each block level of each frame. Motion compensation is a method which is used to describe the transformation of reference image frame to the current image frame. Reference image frame may be a previous or future picture.

Encoding process carried out by three important steps: Prediction, transform and encoding. Compressed bitstream can be achieved by encoding process. While decoding is an complementary process of encoding which involves decoding, inverse transform and reconstruction of video stream.

Prediction uses macroblocks. Prediction is a process of subtracting the current data from the previous coded data to generate a residual. The coded data may be either from a current frame otherwise called as Intra prediction or other frame which is already encoded and transmitted otherwise called as Inter prediction.

Intra prediction is carried out by comparing current macroblock with the previous macroblock within the frame. The macroblock used in the intra prediction had size either 16x16 or 4x4. Inter prediction is carried out by comparing current frame with the previous frame that detects the similar region. In this manner video streams had been compressed in H.264.

The macroblock can span 4x4 to 16x16 block sizes which makes more bandwidth and bit rate for transmission and compression. H.264 allows only 16x16 pixel macroblocks which are too small to be efficient with the video above 1080p resolution. So here we go for H.265 or HEVC standard for video stream compression.

**H.265:**

HEVC development was started by ITU (VCEG) as a replacement of H.264 in 2004. Later in 2007, MPEG also started their research on this particular standard. Then, In the year of 2010 MPEG team up with the ITU to develop HEVC standard. This team is called as JCT-VC (joint collaborative team for video compression). In January 25, 2013 the technical details of HEVC was bring to a conclusion and on April of same year, it was officially announced as a standard.

HEVC uses 64x64 pixel macroblocks which is called as coding tree unit (CTU) allows it to achieve greater encoding efficiency at higher resolution. Improved variable block size segmentation, improved intra prediction, improved motion vector prediction (displacement prediction on different frames), improved motion compensation and additional filtering steps called sample adaptive offset(SAO)are the major upgradation over the previous standard.

SAO filtering increases the signal processing on the encoder side which leads to less computation on decoder side. Advantages of using SAO are High efficiency(HE), Random Access(RA), Low complexity(LC), Low delay(LD).

**LITERATURE SURVEY**

The joint proposal by Tandberg, Nokia and Ericsson that was partially adopted by JCT-VC in the initial test model was taken process as the low complexity operating point. Simulation outputs defined that the proposal achieves a bit rate reduction of around 20%-30% when compared to H.264/AVC High profile. For high definition resolutions of 720p and 1080p, the proposal requires around 35%-50% less bit rate than H.264/AVC at the same subjective quality measured using MOS. The coding efficiency improvement is achieved with very low complexity, which makes the proposal especially suitable for resource constrained use-cases[12].

The new HEVC (High Efficiency Video Coding) standard was developed and standardized together by a ITU-T VCEG and ISO/IEC MPEG. It had several advanced video coding technologies which was based on conventional block-based motion compensated hybrid video coding concept and along some markable differences relative to previous standard. It reduces 50% bit rate for analogous perceptual quality relative to the performance of previous standard [5].

Sample adaptive offset, namely as SAO, was proposed to reduce the distortion between reconstructed pixels and original pixels. The bit rate reduction is about 1.3% in HE(High Efficiency)-RA(Random Access), 2.2% in HE-LD(Low delay), 1.8% in LC(Low complexity)-RA, 3.0% in LC-LD, 3.3-6.3% in Cb component and 3.9-7.6% in Cr component by the proposed SAO for HEVC. In SAO for chroma, the encoding time and decoding time is almost unchanged and also it is adopted in HEVC WD-4.0 and HM-4.0. In proposed SAO system, the encoding time is roughly unchanged and decoding time is increased by 1-3% and also it is adopted in HEVC WD-3.0 and HM-3.0 [1].

SAO locates after deblocking and a modern in-loop filtering technique which reduces distortion between the original samples and reconstructed samples. SAO can improve video compression in both expected and biased measures with acceptable complexity in the system [2].

Combine different edge classes as one new edge class that can remove error in different directions. In this paper, we analyze the performance of each edge offset class, and find that single directional edge pattern is not efficient enough to remove artifacts for the CTB(Coding Tree Block), which contain multiple edges in different directions[7].

Bitmaps are used in the statistics collection of data and to find offset directly, avoiding iterations of multiple values in order to determine the best offset. The SAO estimation architecture is classified into two modules as statistic collection module and parameter determination module. The statistical collection module requires 256 cycle for luma and 64 cycles for Cb and Cr respectively. The parameter determination module requires 64 cycle to process each component of each CTB. This proposed SAO estimation algorithm tends to provide good BD rate performance. Negligible hardware complexity achieves high performance by this algorithm [8].

Class combination for edge offset, pre-decision for band offset in SAO. Class combination is for calculating the four EO in the same time. BO pre-decision decreases the categories of offset from 29 to 4. These two proposal successfully decreased the processing time with some efficiency loss. We also proposed offset merge separation algorithm for saving the efficiency loss by restrict the range of merge offset on CTB level. Experimental outputs gives the clear view that our purposed algorithm could reduce SAO encoding time by about 38% with only 0.16% BD-rate gain and 0.001 dB ΔPSNR loss[6].

Dual clock architecture, to address the separate data flow of Statistics collection(SC) and Parameters Determination(PD) by separately driving SC and PD at high and low speed clock respectively. Two clock frequencies with a relationship of dividend M eliminate the extra hardware and implementation cost. Coarse range selection(CRS) and accumulator bit width reduction(ABR) further reduce the circuit area with no change in the coding efficiency. The architecture which is proposed occupies 51k logic gates with high speed clock of 1.3 GHz and low speed clock of 217 MHz [11].

SAO architectureis implemented in Verilog HDL at RTL(Resistor-Transistor Logic) level and synthesized with UMC 90nm library. The purposed design can be used for decoding 4k x 2k videos @30fps which has substantial applications. In future the hybridization of dataflow and parallel architecture can be explored for SAO filter [13].

Adaptive loop filter is improved. In this filter, multiple feature-based classifiers are used for testing. By calculating confidence level as well as several other ones are proposed by the classifiers to approximate an optimal classifier. How to find an optimal classifier is still an open question [9].

Based on MCALF-1 (Multiple feature-based Classification for ALF) which is extended original of MCALF by various studies on multiple classification algorithms for ALF. MCALF can be called as MCALF-1 by applying of adaptive loop filter and SAO filter simultaneously. Based on MCALF-1 a novel algorithm MCALF-2 and new block-based classifications. Both the algorithms were tested for RA and LDB configurations on the CTC dataset consist of 26 video sequences. Bit-rate reduction of more than 1% compared to the state-of-the-art ALF algorithm can be achieved [10].

A parallel deblocking filter structure for HEVC standard with five pipeline stages. The proposed architecture can filter the edges of two 8x8 block in parallel and filters the luma block in 35 clock cycles and chroma in 20 clock cycles with the overlap of 10 clock cycles. So the overall processing cycles for 16x16 block is 45 clock cycles, and hence the proposed implementation requires 720 clock cycles to process an CTU. It can operate at a frequency of 200MHz and so it support UHD (Ultra-High Definition) applications [15].

AConvolution Neural Network based in-loop filter is proposed as an overall solution to replace all the conventional filters used in video coding. This filter is able to handle various coding distortions. Self-attention blocks can generate higher ratios for the distorted regions and also learn to convert the input QP (Quantization Parameters) values to larger positive or negative values at the defined locations. The proposed ADCNN (Attention based Dual-scale CNN) shows a significant performance gain on all three components in BD-rate savings compared to VVC (Versatile Video Coding), and out performs hybrid solutions using Convolution Neural Network based filtering in VVC [14].

The ability to mitigate video coding artifacts marks a vital step in devising effective methods for video stabilization. PRNU (Photo-Response Non-Uniformitys) estimation and verification procedures need to be adapted to mitigate against disruptive effects of such can also be translated into time complexity gains in PRNU estimation as they allow for using shorter period videos for attribution in source [4].

A CNN (Convolution Neural Network)-based approach to improve the quality of compressed video. An design of RSE-Net (Residual Squeeze-and-Excitation Network) is designed to seperate the extensive characteristics for video. Taking into considering the characteristics of video, a robust model training strategy is developed. The coding efficiency of this approach with only a small number of parameters [3].

**Drawbacks of Previous Works:**In the Statistical Collection part of the SAO(Sample Adaptive Offset) filter, It uses 48 offset bands (32 band offset + 16 edge offset). These leads to unnecessary calculations like a pure white pixel is processed in pure black block for offset. It can be avoided by improving the system

**Motivation:**In general, each sampled pixel is processed on all the 48 offset bands. In the purposed system, it uses an additional filter which allows the sampled pixel to process on 8 offset bands only. The additional filter is designed based on the gray level of sampled pixel which reduces the computation on band offset determination.

**Summary :**

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| --- | --- | --- | --- | --- | --- |
| S.No. | Year | Title | Author | Advantage | Limitations |
| 1 | 2010 | Low Complexity Video Coding and the emerging HEVC Standard | Kemal Ugur, Kenneth Andersson, Arild Fuldseth, Gisle Bjøntegaard, Lars Petter Endresen, Jani Lainema, Antti Hallapuro, Justin Ridge, Dmytro Rusanovskyy, Cixun Zhang, Andrey Norkin, Clinton Priddle, Thomas Rusert, Jonatan Samuelsson, Rickard Sjöberg, Zhuangfei Wu | Emerging of HEVC and the Bit rate reduced by 20-30% compared to H.264/AVC | Encoding time increases |
| 2 | 2012 | Overview of the High Efficiency Video Coding (HEVC) Standard | Gary J. Sullivan, Jens-Rainer Ohm, Woo-Jin Han, Thomas Wiegand, | Bit rate is reduced by 50% relative to the performance of previous standard | Distortion rate is not optimized |
| 3 | 2011 | Sample Adaptive Offset for HEVC | Chih-Ming Fu, Ching-Yeh Chen, Yu-Wen Huang, Shawmin Lei | Distortion rate and bit rate is reduced in various components | No improvements in Filtering process |
| 4 | 2012 | Sample Adaptive Offset in the HEVC Standard | Chih-Ming Fu, Elena Alshina, Alexander Alshin, Yu-Wen Huang, Ching-Yeh Chen, and Chia-Yang Tsai, Chih-Wei Hsu, Shaw-Min Lei, Jeong-Hoon Park and Woo-Jin Han | New in-loop filtering technique is introduced to reduce distortion | Offset determination is not optimized |
| 5 | 2013 | Improved Sample Adaptive Offset for HEVC | Hong Zhang, Oscar C. Au, Yongfang Shi, Wenjing Zhu, Vinit Jakhetiya, Luheng Jia | Improved Edge offset determination technique | Selection of offset is not optimized |
| 6 | 2014 | Fast SAO estimation algorithm and its VLSI architecture | Jiayi Zhu, Dajiang Zhou, Shinji Kimura, Satoshi Goto | Bit map is used to improve offset selection | Offset determination time is more |
| 7 | 2014 | Low complexity SAO in HEVC base on class combination, pre-decision and merge separation | ] Gaoxing Chen, Zhenyu Pei, Zhenyu Liuy and Takeshi Ikenaga | Introduced techniques like Class combination for edge offset and Pre-decision for band offset | Time for Statistics collection and parameter determination is still high |
| 8 | 2017 | A dual-clock VLSI design of H.265 sample adaptive offset estimation for 8k ultra-HD TV encoding | ] J. Zhou, D. Zhou, S. Wang, S. Zhang, T. Yoshimura, S. Goto | separate clock architecture for statistics collection and parameter determination | Hardware architecture requires more size for implementation |
| 9 | 2017 | Area efficient dataflow hardware design of SAO filter for HEVC | Kaustubh Shukla Baldev Swamy, P.Rangababu, | SAO implemented in Verilog-HDL at RTL level and synthesized with UMC 90nm library | Adaptive loop filter is not improved |
| 10 | 2018 | Multiple Feature-based Classifications Adaptive Loop Filter | Johannes Erfurt, Wang- Q lim, Heiko Schwarz, Detlev Marpe, Thomas Wiegand | Adaptive loop filter is improved. | Extended features are not introduced |
| 11 | 2019 | Extended Multiple Feature-based Classifications Adaptive Loop Filter | Johannes Erfurt, Wang-Q-Lim, Heiko Schwarz, Detlev Marpe , Thomas wiegand | Adaptive loop filter is improved. | pipelining is not improved |
| 12 | 2019 | Five-stage pipelined dual-edge deblocking filter architecture for H.265 video codec | Prayline Rajabai Christopher, Sathasivam, | This Architecture can filter the edges of two 8x8 block in parallel . | Filtering method are not advanced |
| 13 | 2019 | Attention-Based Dual-Scale CNN In-Loop Filter for Versatile Video Coding | Ming-Ze Wang, Shaui Wan, Hao Gong and Ming-Yang Ma | Significant performance gain and BD-rate savings compared to VVC. | PRNU estimation is not taken account |
| 14 | 2019 | Mitigatiton of H.264 and H.265 Video Compression for Reliable PRNU Estimation | Enes Altinisik, Kasim Tasdemir, Husrev T. Sencar | Ability to mitigate coding artifacts. | Deep learning approach may use forquality enhancement |
| 15 | 2019 | Extracts extensive characteristics of video | Dandan Ding, Junchao Tong & Lingyi Kong | A deep learning approach for quality enhancement of surveillance video | Band offset calculation can be improved |

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[10]*Johannes Erfurt, Wang-Q-Lim,Heiko Schwarz, Detlev Marpeand Thomas wiegand, “Extended Multiple Feature-based Classifications Adaptive Loop Filter”, in Cambridge University, 14 November 2019.*

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