Adaptive Gaussian Filtering based on Contrast of Luminance for Perceptual Video Coding

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Abstract: This paper proposes an adaptive Gaussian low pass filtering based on the contrast of luminance for perceptual video coding. The proposed adaptive Gaussian low pass filtering employs the contrast threshold of luminance to improve bit saving while maintaining the visual quality. In addition, a block-based filtering decision is also proposed to avoid the over smoothing effect around the high frequency area according to the edge information. Experimental results show that our proposed algorithm can save bitrate by 16% on average or up to 23% with trivially visual quality loss.

Keywords-- **Pre-filter, HEVC, Video Coding**

1. Introduction

Recently, High Efficiency Video Coding (HEVC) has been finalized and standardized since January 2013. HEVC is the latest video coding which can improve 50% of bit rate reduction compared to Advance Video Coding (AVC) under the same subjective quality [1].

For the purpose of coding efficiency improvement on video coding, pre-filter is usually employed before the encoding looping to remove high frequency noise within an image [2]. This can be performed by adopting the human perceptual in the filtering process. The human eyes observe images by distinguishing the luminance changes, which creates a pattern of contrast, as the bulk of visual information through the human visual system (HVS) [3]. In this regard, when the human eye perceives high contrast, this means that there are many different intensities in luminance.

Contrast threshold is one of important parameters to determine the filtering strength generated by the contrast of luminance. Once low contrast is perceived which usually refers to the homogeneous texture, the strong filtering can be employed. As consequence, human eyes cannot perceive any changes of the filtering effects. One approach that can be used to generate this contrast threshold is the Michelson contrast [4]. This approach is suitable to perform the adaptive filtering while maintaining the subjective quality. Furthermore, due to high contrast usually corresponds to edge boundary, the edge information becomes another additional parameter that needs to be considered to control the filtering. Accordingly, over smoothing effect in the high frequency area can be avoided. This way can be applied by designing the filtering decision in order to determine whether it should be filtered or not. In this paper, an adaptive Gaussian low pass filtering is proposed by considering the contrast threshold and the filtering decision which is designed in the block based for perceptual video coding

As a remainder, this paper is organized as follow. Section 2 presents the proposed of the adaptive Gaussian filtering. Section 3 provides the experimental results and discusses the performance of the proposed work. Finally, we conclude and summarize this work in Section 4.

2. The Proposed Method

The proposed work attempts to improve the coding efficiency while minimizing the subjective quality reduction. It is organized by designing contrast threshold calculation, filtering decision, and adaptive Gaussian filtering shown in Figure 1.

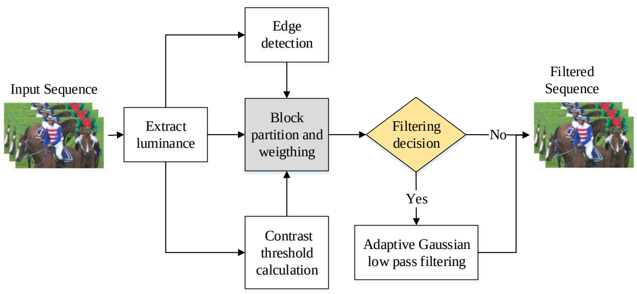

Figure 1. Flow chart of the proposed

We firstly convert the video/image to linear color space followed by extraction of a luminance channel (*F*). We further estimate the local contrast threshold for each pixel of *F*. The Michelson's contrast [4] is employed to calculate the local contrast by 5×5 window expressed as

$$CT(x,y) = \frac{F_{\max} - F_{\min}}{F_{\max} + F_{\min}} \quad (1)$$

where $CT(x, y)$ is the local contrast threshold at position x and y, F_{max} and F_{min} are the local maximum and minimum of F, respectively. And then, it is adjusted to standard deviation (σ) which the lower contrast should be filtered by stronger filtering, defined as

$$\sigma(x,y) = (1 - CT(x,y)) \cdot MSTD \quad (2)$$

where the *MTSD* is the maximum standard deviation value which the filtering effects is still perceptible. In this work, *MTSD* is set to 3.5. Furthermore, a block-based filter decision based on edge information which is detected by Canny operator is employed. Then, the whole picture is divided into 32×32 blocks and each the block weighting (w_i) is calculated based on edge information by

$$w_i = \sum_{s=1}^{32}\sum_{t=1}^{32} E_i(s,t), E = \{0,1\} \quad (3)$$

where E_i is the edge of i-th block which 1 indicates an edge. The block weighting describes how much high frequency in i-th block. It is used to determine whether the block should be filtered under the following condition:

$$F_i = \begin{cases} Filtered & , if\ (w_i < T) \\ Skip & , otherwise \end{cases} \quad (4)$$

The w_i greater than the threshold (T) means there are many high frequency in i-th block. Therefore, the filtering should be skipped or unfiltered due to it will degrade more visually quality. Otherwise, if i-th block holds to be filtered, the adaptive Gaussian low pass filter will be enabled for F in i-th block. Here T is a half of the block size. The coefficient kernel $G_i(x,y)$ at position x and y is generated according to $\sigma(x,y)$. And then, the convolution operation between its kernel and original intensity are performed by

$$g_i(x,y) = F_i(x,y) * G_i(x,y) \quad (5)$$

where (*) is the convolution operator and $g_i(x,y)$ is the convolution operation result at position x and y of i-th block. Due to the human eye is more sensitive in edge boundary, thus it should be controlled by

$$R_i(x,y) = \begin{cases} g_i(x,y) + c \cdot (F_i(x,y) - g_i(x,y)) & , EdgeBoundary \\ g_i(x,y) & , otherwise \end{cases} \quad (6)$$

where R is the result of pre-filter and c is the constraint value which controls the filtering around edge boundary.

3. Performance Evaluation

The proposed preprocessing has been integrated into HEVC reference software HM-16.6. The output of pre-filtering will be set as encoder input. Test sequences are experimented in random access configuration with QP= {22, 27, 32, 37}, under the common test condition (CTC) for HEVC. In order to achieve the gain in coding efficiency, we compared the proposed with anchor which is the conventional HM 16.6 without any pre-filtering.

TABLE I
EXPERIMENTAL RESULTS OF THE PROPOSED ALGORITHM COMPARED TO HM-16.6 WITHOUT PREPROCESSING

Sequence	Sequence	Bitrate Saving
Class C (832x480)	Race Horses	18%
	PartyScene	21%
Class B (1920x1080)	BQ Terrace	23%
	Cactus	13%
	Kimono	4%
Average		**16%**

According to the experimental results as tabulated in Table I, our proposed algorithm can save bitrate up to 23% or 16% on average. To measure the subjective visual quality, the Structural Similarity Index Measurement (SSIM) is conducted. The SSIM is used to measure the picture similarity between the original and the reconstruction of encoding. If the value close to 1 then both pictures are the same, otherwise.

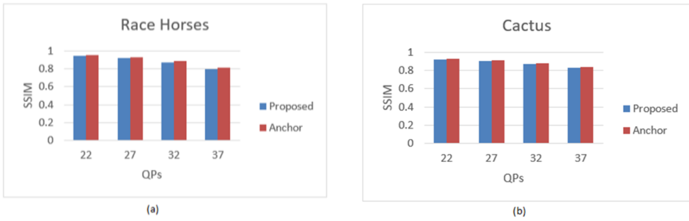

Figure 2. The SSIM measurement of Race horses and Cactus

Figure 2 depicts the SSIM of anchor and the proposed to measure the both subjective quality. The proposed presents negligible SSIM reduction compared to anchor ones. However, it can achieve bitrate saving up to 23%.

4. Conclusions

This paper proposes an adaptive Gaussian low pass filtering based on the contrast threshold for perceptual video coding. By considering a human perceptual such as contrast of luminance and edge information, the proposed algorithm can reduce bitrate by 16% on average with negligible visual reduction.

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