ISSN 2250-3153

Region-based weighted prediction with improved global brightness detection for H.264 Encoder

Prathiba N S, Mrs. Asha G H, Mr. K Shashi kiran

Abstract- This paper presents an efficient region-based WP (weighted prediction) with improved global brightness change detection for real-time H.264 encoder. We improve WP for local brightness changes using the reference reordering, without additional memory bandwidth and computation for ME (motion estimation). A brute force way is choosing the best reference index that minimizes MV cost after performing ME with two references separately. However, it doubles the ME computation too. To reduce the computation, we propose the following MB-based WP.

***Index Terms*-** Video Coding, Weighted Prediction, MV cost, motion estimation, MB-based

I. INTRODUCTION

WP has been introduced in the H.264/MPEG-4 AVC video coding standard to improve coding efficiency during the brightness changes between frames [1]. It can provide high coding efficiency for global brightness changes by determining WP parameters properly [2]. Nevertheless, there are still difficulties in handling local brightness changes because it is a kind of picture-level tool especially for single-slice pictures. WP could lead to significant quality loss if it is not applied carefully. The localized WP was proposed in [3] to handle this problem, which requires syntax changes of H.264/MPEG-4 AVC. Another solution is a brute force approach that encodes all MBs (macroblocks) twice with and without WP and makes a final decision. However, it is not adequate for real-time encoder due to its complexities.

In this paper, we address the local brightness changes with two smart methods, global brightness change detection and MB-based WP. First, with the current and reference frames that are divided into the same number and shapes of regions, we determine if luminance change is global so as to enable or disable WP for a whole picture. Second, when there are local luminance changes, we propose to apply WP adaptively based on the region by using the reference picture reordering to fully leverage the benefit of WP. The proposed algorithms are quite effective for real-time HD (high-definition) H.264 encoder. By carefully configuring reference picture buffer, we can make WP useful for local brightness changes without any additional memory bandwidth and computation in ME. Moreover, the region-based WP can be extended to MB-based only with the marginal increase of computation, which provides the similar performance to a brute force approach.

To compute weighted prediction (WP) parameters, various method and different regions may be considered for weighted prediction parameter calculation, such as, regions where brightness have changed or all regions regardless of how brightness changes locally. In one embodiment, N reference indices may use reference picture reordering and associate N different WP parameters to each of N regions. Then, for each block, the corresponding reference index for motion estimation may be chosen according to its position. When a single block overlaps multiple regions, there are several criteria to decide which region the block is included in. In the current embodiment, we used top-left block position for the decision. Thus, in this case, the block is in the region where top-left pixel of the block is included.

A region based WP method to handle local brightness change as well as improved GBD method is proposed. First, improved GBD is employed to determine if there is local brightness change and to identify such regions. Once local brightness changes are found, region based WP is applied using reference picture reordering to efficiently handle such regions. Then, motion estimation (ME) for each block is performed over one reference index (frame) depending on whether the region, in which the block is located, has brightness change or not.] Such a solution is useful when there are strict limitations on resources, such as, cycle count, memory bandwidth, etc. In the current hardware implementation of H.264 encoder, a single reference is used for ME due to such resource constraints. Since one reference is loaded and one ME per block is needed, no additional computations and memory bandwidth for ME are needed.

II. PROPOSED ALGORITHMS

H.264/MPEG-4 AVC supports the explicit WP method by scaling motion-compensated reference using the multiplicative weighting factor, w and the additive offset, o. The performance of WP depends on not only how to estimate these parameters but also when and how to apply WP. While employing the same method in [2] for WP parameter estimation, we focus on the latter in this work. To describe the algorithms, we assume the case of single-slice frame picture coding with a single reference frame, without loss of generality.

2.1 Global brightness change detection (GBCD)

We divide the current and the reference frame into 5 regions as shown in Fig. 2. Then we apply the following GBCD method, by which we can identify as well the regions that have brightness changes.

1. Compute mean and variance of the n-th regions of the current and the reference picture, which denoted by $Mcur\ (n)$, $Mref\ (n)$, $Vcur\ (n)$ and $Vref\ (n)$, respectively. And calculate absolute difference between two mean values,

Mdiff (n) = |*Mcur (n)* – *Mref (n)*|.

2. Compare *Mdiff (n)* to *TH*, which we set to 1 in the experiments. If *Mdiff (n)* is larger than *TH*, increase *Rcount*, which is initialized to 0, by 1.

3. Repeat steps 1 and 2 for all 5 regions.

4. Check if either *Vcur (n)* – *Vref (n)* _ 0 or *Vcur (n)* – *Vref (n)* 0 for all regions. Based on our observation that the variances of all regions increase or decrease with fadein or fade-out, respectively, as shown in Figure 1, this condition checks if the mean values change by fading. If it is true, we set *Fade* to 1, otherwise, set *Fade* to 0. If *Fade* is equal to 1 and *Rcount* is equal to 5, we estimate (*w*, *o*) and associate them to refidx = 0. Otherwise, we disable WP. In both cases, ME is done w.r.t. refidx = 0 for all MBs.

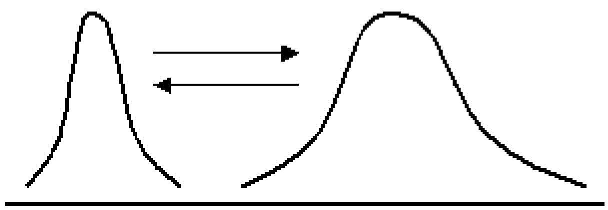

Fig. 1. Histogram changes with fade-in and fade-out. Variances change monotonically for all regions in general.

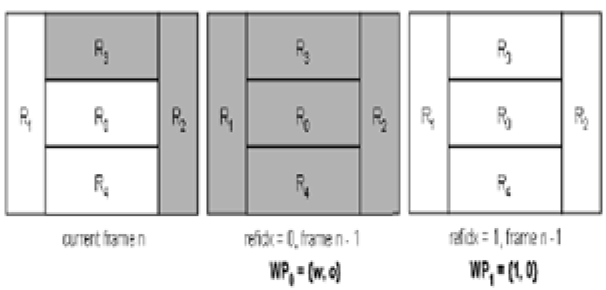

Fig 2: Reference picture reordering for local brightness changes. Shaded regions in the current frame have brightness change with respect to the reference.

FIG. 2 is an embodiment of a local brightness changes and association to reference index. In FIG. 1, the frames are divided into 5 rectangular regions; two of frames include luminance change (gray regions) and the others do not (white regions). In such a case, the reference list is reordered to put the same reference frame (frame t-1) into refidx=1 as well. Then, the computed WP parameters (WP0) is associated with refidx=0 and zero WP parameters (WP1) with refidx=1. Then we perform ME using refidx=0 for MBs in the gray regions and refidx=1 for MBs in the white regions.

2.2. Region-based WP

In the region-based weighted prediction, if the fade is set to 1 and N_{min}<Rcount<N_{max}, the reference frame is reordered in order for the same reference frames to sit in two places, refidx=0 and refidx=1, respectively. In such a case, WP parameters are computed and associated to refidx equal to 0 and zero WP parameters are associated to refldx equal to 1. The encoder may send reference reordering syntaxes for decoders. However, when encoding each MB, if the MB is in the region with brightness change, ME is performed with refidx equal to 0. However, if the MB is in the regions without brightness change, ME is performed with refidx equal to 1. In one embodiment, if 2 reference frames are used without global brightness change, coding gains are lost due to the increased overhead bits to encode reference index. Such losses are very noticeable with normal sequences that have no fade-in, fade-out and brightness changes.

In one embodiment, one may consider the percentage of regions with brightness change for it. For example, the number of regions with brightness change is smaller than the other, zero WP may be associated with refidx=0. This is important because it affects the number of skipped blocks, whose refidx should be 0.

FIG 3: is an embodiment of a flow diagram depicting a method for region-based weighted prediction with improved global brightness detection. The method starts at step 1 and continues to step 2. At step 2, the method determines if a change in global brightness was detected. If a change was detected, the method proceeds to step 3, wherein weighted prediction parameters are calculated. Otherwise, the method proceeds to step 4, wherein the method determines local brightness has changed. If there is no change, the method proceeds to step 5, wherein the weighted prediction parameters are set to zero (0). Otherwise, the method proceeds to step 10.

From steps 3 and 5, the method proceeds to step 6, wherein the method sets micro block index to zero (0) and proceeds to step 7. At step 7, the method sets motion estimation with refldx to zero (0). At step 8, the method determines if it is the last micro block. If it is not the last block, the method proceeds to step 9 and sets micro block in increased by one (1). The method proceeds from step 9 to step 7. From step 4, if the local brightness changed, the method proceeds to step 10. At step 10, the method calculates the weighted prediction parameters and reference re-ordering. At step 11, the method step the micro block index to zero (0). At step 12, the method determines if the micro block is in the region of luminance change. It is in the region, the method proceeds to step 14. At step 14, the method calculates motion estimation with refidx set to zero (0). Otherwise, the method proceeds from step 12 to step 13, wherein the method calculates motion estimation with refidx set to one (1) and weighted prediction parameters set to zero.

From steps 13 and 14, the method proceeds to step 15, wherein the method determines if it is the last micro block. If it is not the last micro block, the method proceeds to step 16, wherein the micro block index is incremented by one (1). From step 16, the method returns to step 12. Otherwise, the method proceeds from step 15 to step 17. The method ends at step 17.

ISSN 2250-3153

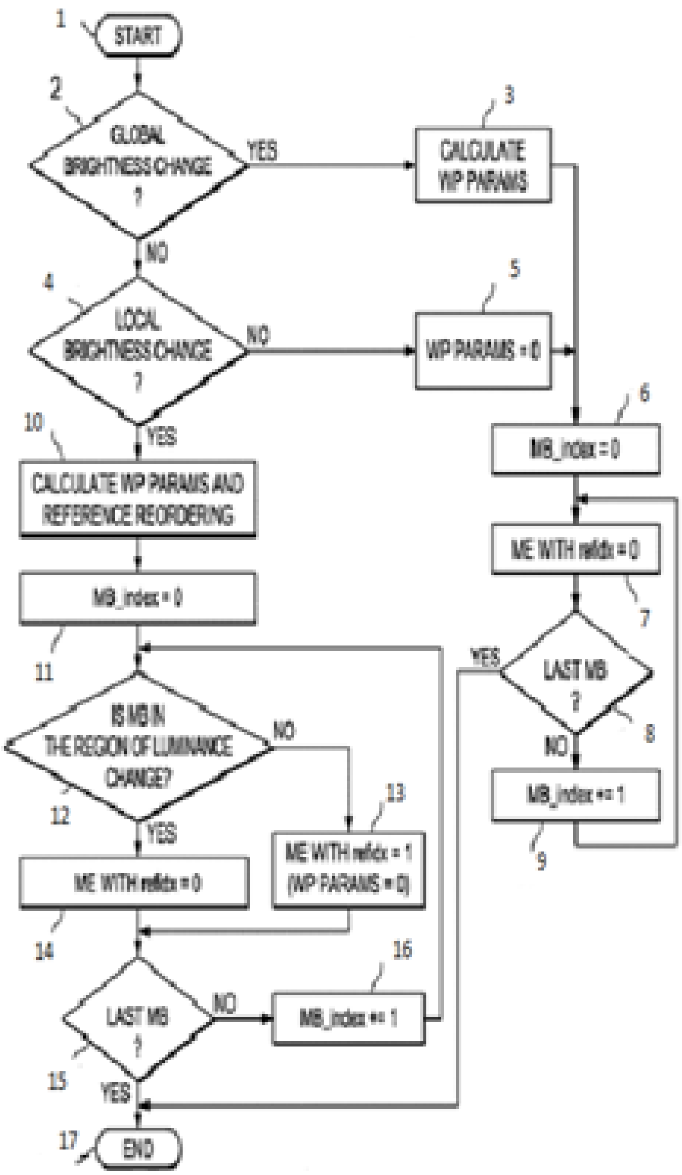

Fig 3: Flow of this paper

The region-based WP can be extended to block based or macro-block (MB) based weighted prediction with marginal computation increase, but without any increase of memory bandwidth. In another embodiment, macro-block based weighted predictions are calculated with marginal computation increase, but without any increase of memory bandwidth. Thus, global brightness change detection is improved. Improving global brightness change detection (GBD) in order to produce a more accurate decision. If there is no brightness change or global brightness change, on/off weighted prediction switch is switched globally. If we detect local brightness change, we apply weighted prediction with reference list reordering to put the same reference in multiple reference list. With reference reordering, both region-based WP and MB-based weighted prediction are enabled.
As a result, the quality loss by improved GBD method is minimized. The improved GBD is also critical to region-based WP. By carefull decision on the use of region-based WP, the coding gain is maximized by region-based WP and the overhead bits to encoder reference index are minimized. The proposed MB-based WP with best MV cost check requires motion estimation only with 1 reference for each block, but have the similar performance with microblock based WP with motion estimation with 2 references. Hence, better quality is achieved with marginal increase of computational complexity.

MB-based WP with final MV cost check: If Fade=1 and N_{min}<Rcount<N_{max}, we reorder the reference frame so that the same reference frames sits in two places, refidx=0 and refidx=1, respectively.

WP parameters are calculated and associated to refidx equal to 0 and associate zero WP parameters to refidx equal to 1. The encoder should send reference reordering syntaxes for decoders. When encoding each MB, motion estimation with zero WP parameters (refidx=1) are calculated first and get the best MV and its MV cost, which are denoted by MV_1 and $MVCost_1$. Then, for MV_1, MV cost w.r.t. non-zero WP parameters (refidx=0) are calculated (denoted by MV_0 and $MVCost_0$). Decide the best reference index by comparing $MVCost_1$ and MVCost.

In the above algorithm, this is an issue on which reference index we will use for motion estimation. Motion estimation gets better when the actual content is not hampered by brightness change. Based on this fact, we can do motion estimation with non-zero WP in case of fade-in (i.e. $v_{cur}(n)-v_{ref}(n)>=0$). The above MB-based WP can be modified to use 2 references for motion estimation instead of final MV cost check. It is supposed to show the best performance. But the computational complexity will increase. We use this 2-ref MB-based WP as bench mark to evaluate the region-based WP and the (1-ref) MB-based WP with final MV cost check.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

III. RESULTS AND CONCLUSIONS

For the experiments, we used normal 1080p sequences and 1080p and 720p trailer sequences which have lots of fading, flashing and scene changes. We encoded them into the IPPP structure with a single reference frame using the following methods: (0) No WP, (1) Always WP, (2) GBD + WP, (3) GBD + region-based WP, (4) GBD + MB-based WP and (5) GBD + brute force MB-based WP. Tables 1 and 2 show the BD-PSNR [5] of (1) – (5) over (0) for the normal and the trailer sequences, respectively.

TABLE 1
PSNR IMPROVEMENTS OF (1) – (5) OVER (0) FOR NORMAL SEQUENCES

	(1) over (0)	(2) over (0)	(3) over (0)	(4) over (0)	(5) over (0)
stractor	-0.115	-0.000	-0.006	-0.000	-0.003
sIceHockey	-0.366	-0.001	-0.019	-0.013	-0.013
sjuggle	-0.329	-0.002	-0.007	-0.004	-0.006
smaninrest	-0.461	-0.005	-0.042	0.019	0.023
sPanIceHockey	-1.201	-0.005	-0.024	-0.013	-0.014
sfish	-0.882	-0.001	-0.051	-0.018	-0.023
satonement	-0.431	-0.000	-0.042	-0.015	-0.019
sfoolsgold	-0.426	-0.044	-0.044	-0.044	-0.044
Average	**-0.526**	**-0.007**	**-0.029**	**-0.011**	**-0.011**

TABLE 2
PSNR IMPROVEMENTS OF (1) – (5) OVER (0) FOR TRAILER SEQUENCES

	(1) over (0)	(2) over (0)	(3) over (0)	(4) over (0)	(5) over (0)
9tlr	0.903	0.384	0.630	0.667	0.666
999tlr	0.541	0.254	0.512	0.548	0.550
300	0.402	0.089	0.508	0.514	0.523
adoration	1.644	0.480	1.465	1.486	1.539
astroboy	0.647	1.043	1.172	1.188	1.193
17again	-0.285	0.221	0.198	0.208	0.204
adamtlra	-1.994	-0.044	-0.334	-0.161	-0.191
guardian	-0.374	-0.048	-0.144	-0.076	-0.085
Average	**0.185**	**0.297**	**0.500**	**0.546**	**0.549**

We observe that applying WP without GBCD could be disastrous even for normal sequences. Because the GBCD is quite good in identifying brightness changes, we can remove such losses by (2), (3) and (4) for normal sequences as shown in Table 1. The advantage of the MB-based methods becomes obvious in Table 2. Applying only GBCD decreases coding gains for several trailer sequences. However, (3) and (4) show the coding gain close to (1) for these sequences.

Furthermore, the MB-based WP not only improves average PSNRs but also reduces quality losses caused by the region based WP for 'adamtlra' and 'guardian' sequences.

We can conclude that the proposed MB-based WP deals with local brightness changes successfully without additional memory bandwidth and computation for ME. As shown in Tables 1 and 2, the proposed MB-based WP achieves the similar performance to the brute force MB-based WP, with the additional computation only for a single MV cost.

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AUTHORS

First Author – Prathiba N S, 4th sem, Mtech, MCE Hassan, nsprathi@gmail.com, +91 9845502532

Second Author – Mrs. Asha G H, Associate Professor, Dept. of E&C Engineering, MCE Hassan, India

Third Author – Mr. K Shashi kiran, Proprietor, VTech, Bangalore, India