An Efficient Method for Early Detecting All-Zero Blocks in H.264 Video Encoding

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Abstract

In H.264 video coding, the effect of the rate-distortion optimization (RDO) on compression efficiency increases while its complexity accounts for an important part of the computation burden. Discrete cosine transform (DCT) is one of the main operations performed as a part of the RDO operation. Therefore, the elimination of DCT operations may lead to a significant reduction of the computational burden in RDO. An early detecting all-zero blocks (AZB) is an efficient DCT elimination technique in currently state-of-art video coding standards. The computations of DCT and quantization can be remarkably reduced if AZB are detected prior to DCT and quantization. This paper presents an efficient method for early AZB by combining both Parseval energy conservation theorem and the successive elimination algorithm (SEA). A mathematical inequality is derived from Parseval theorem, and we apply SEA for motion estimation (ME) to more efficient detecting AZBs. The simulation results show that the proposed method achieves approximately a 12%~22% computational saving compared to the existing methods. Furthermore, when the proposed method is implemented with other fast detection algorithms, it can further improve AZB detection ratio without any video-quality degradation.
Keywords: video coding, H.264, Parseval energy conservation

1. Introduction

The current H.264 standard can achieve much higher coding efficiency than the previous standards such as MPEG-1/2/4 and H.261/H.263 [1]. However, extremely high computational complexity is required in the encoder, which limits the real-time implementation of H.264. In recent years, a number of efforts have been made to study fast algorithms in mode selection and motion estimation (ME) for H.264 encoding because it occupies about 70% of the total encoding computations [2-3]. As the complexity of ME and mode selection are reduced, we need to optimize other modules to further speed up video encoding. On the other hand, the discrete cosine transform (DCT) and quantization (Q) are the other two important modules which take up about 16% of the total computations in a DSP-based H.264 encoder [4]. In low bit-rate video applications, all-zero blocks (AZB) for DCT coefficients are quite common [5]. The computations of DCT and Q (DCT/Q) need not be performed if AZBs can be detected prior to DCT/Q. Thus, early detecting of AZBs can effectively reduce the computational complexity. A number of early detection techniques [6-10] of all-zero DCT blocks have been studied for the integer 4×4 DCT based H.264 encoder without video quality degradation.

Moon *et al*. [6] analyzed the characteristics of the integer DCT/Q in H.264 encoder based on Sousa's algorithm [7], and proposed a more efficient condition to detect more AZBs. Based on Moon's method, Su [8] and Wang *et al*. [9] proposed a sufficient condition to obtain wider range of threshold to detect more AZBS than Moon's algorithm. However, it is bounded to detect AZBs, based on the characteristics of both DCT formula and quantization from [6-9]. According to the content of image, Xie *et al*. [10] applied Parseval energy conservation theorem to derive a more effective algorithm for detecting the AZB. But, Xie's method has a heavy computational load result in reducing the efficiency of encoding. To further detect AZBs, Zhang *et al*. [11] adopted an adaptive method by using a threshold of QP values. However, the thresholds are sensitive to the contents of video sequence.

In this paper, we present a more efficient and fast algorithm for early detecting AZB by combining Parseval energy conservation theorem and the successive elimination algorithm (SEA) [12] adopted in motion estimation (ME) module. Our algorithm can improve and speed up Xie's algorithm. Furthermore, when the proposed algorithm is implemented with other fast detection algorithms, it can further improve AZB detection ratio without any video-quality degradation.

The rest of this paper is organized as follows. The DCT and quantization applied to H.264 are discussed in Section 2. An overview of related work on AZBs detecting in H.264 is provided in Section 3. Section 4 describes how to apply the proposed method in H.264. The experimental results are presented in Section 5. And Section 6 concludes the proposed method.

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2. DCT and Quantization in H.264

In H.264, the DCT is an integer transform applied to 4×4 blocks of residual data to avoid inverse transform mismatch problems. The core part of the integer 4×4 DCT can be implemented by using only additions and shift. A scaling multiplication is integrated into the quantizationto reduce the total number of multiplications. The integer 4×4 DCT is

Table 1: Relationship between position and value of *PF*.

Position	PF
(0,0), (2,0), (0,2), (2,2)	a^2
(1,1), (1,3), (3,1), (3,3)	$b^2/4$
other	$ab/2$

$$Y = AXA^T \tag{1}$$

where X is the matrix of residual signal, and Y is the matrix of transformed coefficients. A is a 4×4 transformation matrix. The elements of matrix A are

$$A = \begin{bmatrix} a & a & a & a \\ b & c & -c & -b \\ a & -a & -a & a \\ c & -b & b & c \end{bmatrix} \tag{2}$$

where $a = 1/2$, $b = \sqrt{1/2}\cos(\pi/8)$, $c = \sqrt{1/2}\cos(3\pi/8)$.

In order to simplify the implementation, the 4×4 DCT in H.264 is approximated to the following form

$$\begin{aligned} Y &= \left(CXC^T\right) \otimes E \\ &= \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \cdot [X] \cdot \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 2 & -1 \end{bmatrix} \otimes \\ & \begin{bmatrix} a^2 & \frac{ab}{2} & a^2 & \frac{ab}{2} \\ \frac{ab}{2} & \frac{b^2}{4} & \frac{ab}{2} & \frac{b^2}{4} \\ a^2 & \frac{ab}{2} & a^2 & \frac{ab}{2} \\ \frac{ab}{2} & \frac{b^2}{4} & \frac{ab}{2} & \frac{b^2}{4} \end{bmatrix} \end{aligned} \tag{3}$$

where $a = 1/2$, $b = \sqrt{2/5}$, E is scaling factor and the symbol $\otimes$ indicates that each element of CXC^T is multiplied by the scaling factor in the position in matrix E. The scalar quantization operation in H.264 is defined as

$$Z_{ij} = round(Y_{ij} / Qstep) \tag{4}$$

where Z_{ij} is quantized coefficient , Y_{ij} is DCT coefficient, and $Qstep$ is quantization parameter (QP) ranging from 0 to 51. Because of $Y_{ij} = W_{ij} \cdot PF$, Z_{ij} can be written as

$$Z_{ij} = round(W_{ij} \cdot \frac{PF}{Qstep}) \tag{5}$$

where $W_{ij} = CXC^T$ is the core transform of DCT, and PF is position factor. The relationship of position and the value of PF are summarized in Table 1. To avoid the floating multiplication of PF and division of $Qstep$, an integral coefficient MF (multiplication factor) and binary right shift are applied to H.264, respectively. The quantized coefficient Z_{ij} $(0 \le i, j \le 3)$ is written as

$$\begin{aligned} |Z_{ij}| &= \left(|W_{ij}| \cdot MF + f\right) >> qbits \\ sign\left(Z_{ij}\right) &= sign\left(W_{ij}\right) \end{aligned} \tag{6}$$

where f is a constant for reducing the error caused by quantization, and $f = 2^{qbits}/3$ for intra blocks or $f = 2^{qbits}/6$ for inter blocks, the symbol >> denotes a binary shift right, $sign(a)$ takes the sign of a, and $qbits = 15 + QP/6$. The value of MF is a function of QP and is provided by a periodic table as follow

$$MF = M\left(QP\%6, r\right) = \begin{bmatrix} 5243 & 8066 & 13107 \\ 4660 & 7490 & 11916 \\ 4194 & 6554 & 10082 \\ 3647 & 5825 & 9362 \\ 3355 & 5243 & 8192 \\ 2893 & 4559 & 7282 \end{bmatrix} \tag{7}$$

where $r = 2 - (i\,\%2) - (j\,\%2)$, % denotes the modular operator.

3. Overview of AZB Detecting Methods

3.1 Sousa's and Moon's Method

Sousa [7] performs a simple sufficient condition to detect AZB for 8×8 DCT without video quality degradation. However, Sousa's algorithm cannot be directly applied to H.264, since H264 uses the integer 4×4 DCT. Moon *et al*. [6] proposed a modified formula for H.264 video coding by deriving a more precise sufficient condition to detect AZB. The AZB detection formula for Moon's method is written as follows

$$SAD = \sum_{i=0}^{3}\sum_{j=0}^{3}\left|x_{ij}\right| < \frac{2^{15+(QP/6)} - f}{4 \cdot M(QP\%6,0)} \tag{8}$$

where $\sum_{i=0}^{3}\sum_{j=0}^{3}\left|x_{ij}\right|$ is the sum absolute of difference (SAD). The *SAD* can be obtained in ME process, and it doesn't need extra operation. The threshold of AZB detecting obtained by Moon's algorithm can be written as

$$T(r) = \frac{2^{15+(QP/6)} - f}{C(r) \cdot M\left(QP\%6, r\right)} \quad for \quad r = 0,1,2 \tag{9}$$

where $C(r) = 2^{2-r}$, and $T(0) < T(1) < T(2)$. Therefore, the AZB detection in H.264 for Moon's method is summarized as follows

$$\mathrm{SAD} \le T(r) = \frac{2^{15+(QP/6)} - f}{C(r) \cdot M\left(QP\%6, r\right)} \quad for \quad r = 0,1,2 \tag{10}$$

Table 2 shows the relationships between *SAD* and threshold $T(r)$. It is interestingly noted that $T(0)$ is exactly identical to Sousa's condition. In other words, we can find that Sousa's algorithm can detect AZB in M0 mode only.

Table 2: Relationships between *SAD* and threshold $T(r)$ for different modes.

Modes	Conditions	zero frequency components
M0	$\mathrm{SAD}_{\min} < \mathrm{T}(0)$	r =0, 1, 2
M1	$\mathrm{T}(0) \le \mathrm{SAD}_{\min} < \mathrm{T}(1)$	r = 1,2
M2	$\mathrm{T}(1) \le \mathrm{SAD}_{\min} < \mathrm{T}(2)$	r = 2
M3	$\mathrm{T}(2) \le \mathrm{SAD}_{\min}$	None

In order to detect AZB in M1 mode, Moon *et al*. [6] derived the conditions which satisfied the quantized coefficients corresponding to frequency components of $r = 0$ being zero for M1 mode. The threshold value of Moon's method is

$$SAD_{th} = T(0) + (\lambda / 2) \tag{11}$$

where $T(0)$ and λ are specified in [6] and its threshold is higher than that of Sousa's method.

3.2 Su's and Wang's Method

Based on Moon's approach, Su [8] derived the sufficient condition which satisfied the quantized coefficients corresponding to frequency components of $r = 0$, 1 being zero for M*2* mode to detect more AZB. The threshold is defined as follows:

$$\begin{aligned} SAD &< \frac{2^{16+(QP/6)} - f}{M(QP\%6,0)} - 5\max\{S_i\} \\ &= 4T(0) - 5\max\{S_i\} \qquad for \quad r = 0 \\ SAD &< \frac{2^{16+(QP/6)} - f}{M(QP\%6,1)} - 2\max\{S_i\} \\ &= 2T(0) - 2\max\{S_i\} \qquad for \quad r = 1 \end{aligned} \tag{12}$$

where S_i for i = 0~3 is

$$\begin{aligned} S_0 &= |x_{00}| + |x_{03}| + |x_{30}| + |x_{33}| \\ S_1 &= |x_{01}| + |x_{02}| + |x_{31}| + |x_{32}| \\ S_2 &= |x_{10}| + |x_{13}| + |x_{20}| + |x_{23}| \\ S_3 &= |x_{11}| + |x_{12}| + |x_{21}| + |x_{22}| \end{aligned} \tag{13}$$

Wang's method [9] can detect more AZBs compared with Su's method because the threshold value is larger than that of Su's. The threshold in Wang's method is defined as follows

$$\begin{aligned} &SAD = 4T(0) - \max\left\{\begin{matrix} S_0 + S_{01} + S_{02},\ S_1 + \\ S_{01} + S_{13},\ S_2 + S_{02} \\ + S_{23},\ S_3 + S_{13} + S_{23} \end{matrix}\right\} for\ r = 0 \\ &SAD < 2T(0) - 2\max\{S_{01}, S_{02}, S_{13}, S_{23}\} \quad for \quad r = 1 \end{aligned} \tag{14}$$

where $S_{02} = S_0 + S_2$, $S_{13} = S_1 + S_3$, $S_{01} = S_0 + S_1$, and $S_{23} = S_2 + S_3$.

Although the ensemble average detection ratio for AZBs by Wang's method is higher than other AZB detecting methods, it is difficult to further detect more AZB since Wang's method which uses the characteristics of DCT and quantization. To further detect more AZB in M3 mode, we need to study the new viewpoints for AZB detecting.

3.3 Xie's Method

Those above-mentioned methods are mainly based on the characteristics of DCT and quantization to derive a more precise sufficient condition for AZB detecting. Xie *et al*. [10] established a AZB detection method based on considering the content of image by Parserval energy conservation theorem. The derivation of Xie's method is described as follow.

The signal in time domain is defined as $x(n)$, and Parseval theorem can be obtained

$$\begin{aligned} X(k) &= DFT[x(n)] \\ \sum_{n=0}^{N-1}|x(n)|^2 &= \sum_{k=0}^{N-1}|X(k)|^2 \end{aligned} \quad (15)$$

where $X(k)$ is signal $x(n)$ in frequency domain. The expression can be rewritten as

$$\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e^2(x,y) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} E^2(i,j) \quad (16)$$

where $e(x,y)$ is residual samples and $E(i,j)$ is the DCT coefficients of residual. $E(0,0)$ presents DC component, and AC component is presented as

$$\sum_{i+j\neq 0} E^2(u,v) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e^2(x,y) - E^2(0,0) \quad (17)$$

where $E(0,0) = \frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e(x,y)$.

The criterion of AZB in Xie's method can be obtained

$$\begin{cases} |E(0,0)| \prec qscaler\_dc \\ \sum_{u+v\neq 0} E^2(i,j) \prec qscaler\_ac \end{cases} \quad (18)$$

where $qscaler$ is quantization scale, and the value of $qscaler$ is determined by video coding standards. The relation between Z_{ij} and $E(i,j)$ is

$$|\mathrm{Z}_{ij}| = [\frac{|E(i,j)|}{Qstep} + \frac{1}{6}] \quad (19)$$

where symbol [ ] denotes the rounding-off operation, and the condition of $|Z_{ij}| = 0$ is

$$|E(i,j)| \prec \frac{5}{6} \times Qstep \quad (20)$$

where $Qstep = 0.625 \times 2^{qp/6}$ in H.264.

Consider the property of those above, the threshold in Xie's method in H.264 is defined as follows

$$\begin{cases} \left|\frac{1}{4}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e(x,y)\right| < T_{dc} \\ \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e^2(x,y) - \left|\frac{1}{4}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e(x,y)\right|^2 < T_{ac} \end{cases} \quad (21)$$

where $T_{dc} = 5/6\, Qstep$ and $T_{ac} = (5/6\, Qstep)^2$. Eq. (21) shows that Xie's detection needs 17 multiplications, 31 addition and 1-bit right shift operation. It causes that Xie's method has a heavy computational load.

3.4 Comparisons of AZB Detection Methods

The existing methods are simulated at the software platform with the version of JM 18.1 [13], and the setting of configuration in our experiments is one reference frame, baseline profile with picture structure of IPP….P, 33×33 for searching widow, and rate-distortion optimization (RDO) off. To examine the existing method in different conditions, six benchmark video sequences with different size and motion activities are used. All sequences including 100 frames in QCIF (Foreman, Silent and Salesman) and CIF (Container, Paris and Akiyo) are encoded, respectively. In addition, in order to examine the performance at different bit rates, five QP values including 24, 28, 32, 36 and 40 are used in our experiment. The detection ratio (DR) of AZB is defined as

$$DR = \frac{detected\ \text{AZBs}}{actual\ \text{AZBs}} \times 100\% \quad (22)$$

The simulation results of the *DR* for the existing methods are shown in Figure 1. From Fig. 1, we can find that Sousa's and Moon's methods have the lower detection ratio because they are only deduced in M0 and M1, respectively. On the other hand, we also find that Su's, Wang's and Xie's methods achieve higher detection ration because first both methods are deduced in M2, and Xie's method is based on considering the content of images. Since the AC part of Xie's is not precise, the DR of Xie's method is not better than Su's or Wang's. In addition, the lower active sequence has the higher DR when using the existing methods. For example, the Akiyo sequence has the higher DR than other AZB detecting methods.

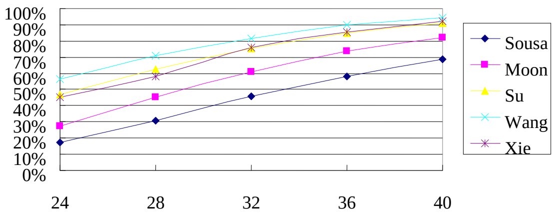
4. Proposed Detecting Method

4.1 Integrated SEA and Parseval's Theorem

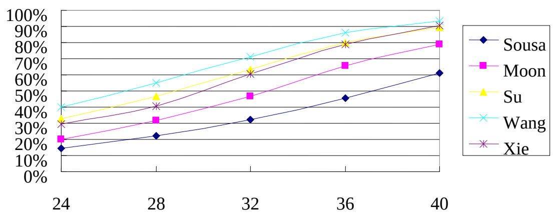
Sousa, Moon, Su and Wang derived the sufficient conditions to detect AZBs by using the characteristics of DCT and quantization. However, it is difficult to further detect more AZBs since them [6-9]. Xie used the content of images by Parserval energy conservation theorem to derive the DC and AC sufficient conditions to detect AZBs [10]. Although Xie's detection rate is not better than Su's or Wang's, some AZBs only can be detected by Xie's method. But the AZB detection needs 17 multiplications, 31 addition and 1-bit right shift operation. It causes that Xie's method has a heavy computational load. In order to further reduce computational complexity in [10], we deeply analyze the relationships between Parserval's energy conservation theorem and fast lossless motion estimations (ME) in H.264. From Eq. (21), we find that there are two measuring parameters including sum norm of difference (SND) and sum of squared error (SSE) for the sufficient condition to detect AZBs. The SND is shown as follows

$$\left|\frac{1}{4}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}e(x,y)\right| \qquad (23)$$

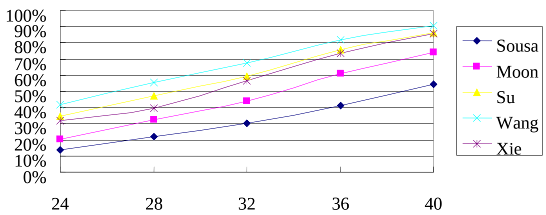
However, the SND and SSE cannot be directly obtained from ME in the joint model (JM) software [12] of H.264.



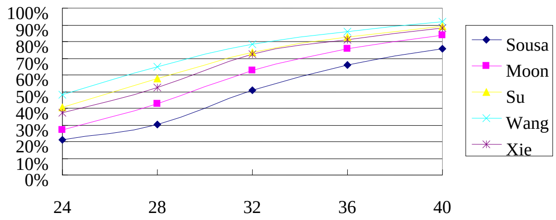
(a)



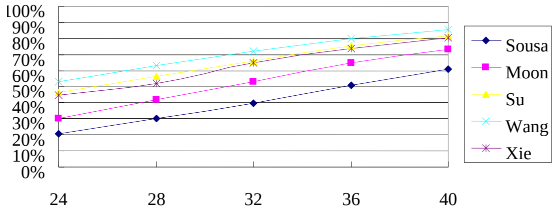
(b)



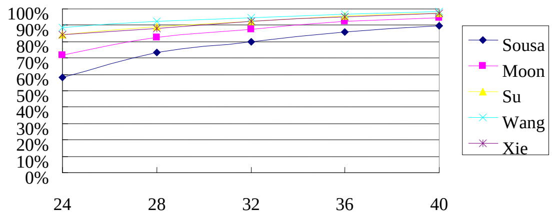
(c)



(d)



(e)



(f)

Figure 1: The DR of AZB for the existing methods. (a) Foreman (b) Silent (c) Salesman (d) Container (e) Paris (f) Akiyo

Xie's method needs extra computational load. To combat the above problem, we adopt the successive elimination algorithm (SEA) [13] for the ME in the JM platform to increase the efficiency of early detecting AZB.

From Eq. (21), we analyze the SND for sufficient condition in dc part as follows

$$\begin{aligned}&\left|\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}e(x,y)\right|\\ &=\left|\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(0,0)+f(0,1)+\ldots+f(N\text{-}1,N\text{-}1)\right|.\end{aligned} \qquad (24)$$

Eq. (23) can be rewritten based on using SEA as

$$\begin{aligned}&\left|\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(x_{ij}-y_{ij})\right|\\ &=\left|(x_{00}-y_{00})+(x_{01}-y_{01})+\cdots+(x_{N\text{-}1N\text{-}1}-y_{N\text{-}1N\text{-}1})\right|\\ &=\left|(x_{00}+x_{01}+\cdots+x_{N\text{-}1N\text{-}1})-(y_{00}+y_{01}+\cdots+y_{N\text{-}1N\text{-}1}\right|\end{aligned} \qquad (25)$$

where x is the pixel value of coding blocks, and y is the pixel value of candidate blocks in search windows. The SEA uses the Cauchy-Schwarz inequality from Eq. (25) and obtains two inequalities as

$$R - M(x, y) \le SAD_{\min}$$
$$M(x, y) - R \le SAD_{\min} \quad (26)$$

where R is the SND of the current block, and $M(x, y)$ is SND of candidate blocks in the search window. We can rewrite the Eq. (26) as compared with Xie's method as

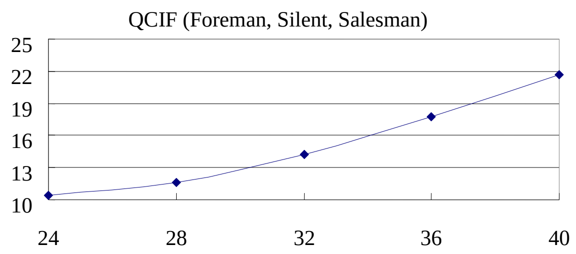
$$|R - M(x, y)| = SND \le SAD_{\min} \quad (27)$$

From Eqs. (24) and (27), we can efficiently reduce the computational load when we adopt the SEA as ME module implemented in H.264 rather than other ME module. It fully matched Xie's method when using the SND measurement in ME process.

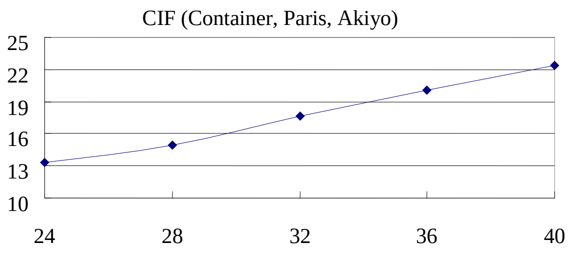
4.2 Implemented with Other Detection Algorithms

Existing methods [6-10] for early detecting AZBS in H.264 encoder, they mainly use analyzed the characteristics of the integer DCT and Q. However, the ability of detecting AZBs is bounded when only using these characteristics, including Moon's, Su's and Wang's methods. To further increase AZB detection ratio, the proposed algorithm is implemented with these detection algorithms. The new integrated AZB detecting method can be summarized as follows

Step1: Check whether the value of SAD is less than the threshold value of exiting AZB method. If it is true, the AZB is detected and skips the DCT/Q module. Otherwise go to step2.
Step2: Check whether the value of SND is less than $SAD_{\min}$. If it is true, the AZB is detected and skips the DCT/Q module. Otherwise go to step3.
Step3: Perform the DCT/Q module.



(a)



(b)

Figure 2: The average CSR of the proposed method as comparedwith Xie's method. (a) QCIF sequence (b) CIF sequence.

5. Simulation Results

The proposed algorithm is implemented within version of JM 18.1 and the configuration in our experiments in one reference frame, baseline profile with picture structure of IPP….P, 33×33 for searching widow, and rate-distortion optimization (RDO) off. To examine the proposed algorithm in different conditions, six benchmark video sequences with different size and motion activities are used. All sequences are 100 frames in QCIF, and CIF are encoded. In addition, in order to examine the performance at different bit rates, four QP values including 28, 32, 36 and 40 are used in our experiment.

In order to evaluate the overall performance, the proposed method has been applied to AZB detection prior to DCT and early termination criterion of SEA motion estimation in H.264, respectively. The computation saving ratio (CSR) which compares the AZB blocks detected using the proposed method, and Xie's method is shown in Fig 2. The *CSR* is defined as

$$CSR = \left(1 - \frac{TC\ of\ proposed\ method}{TC\ of\ Xie's\ method}\right) \times 100\% \quad (28)$$

CSR is the average computational saving ratio of video sequences, and *TC* is the total computation. From Fig. 2, the proposed algorithm achieves 10.38% ~ 22.37% more computational saving than Xie's in all sequences on average. This is because our algorithm can further reduce the computational load in the sufficient conditions in dc and ac parts. From Fig. 2, we also can find our method has higher computational ratio when QP is higher.

Tables 3 and 4 show the comparison of the detection ratio in Moon's, Su's, Wang's, and proposed the algorithm integrated with these algorithms using QCIF and CIF sequences, respectively.

Table 3: Comparisons of the detection ratio using QCIF.

QP	Methods	Foreman	Silent	Salesman
28	Moon	45.49%	31.75%	32.31%
	Proposed +Moon	64.32%	45.6%	44.79%
	Su	62.83%	46.87%	46.99%
	Proposed +Su	68.98%	51.29%	50.22%
	Wang	71.08%	55.2%	55.36%
	Proposed +Wang	73.78%	57.18%	56.6%
32	Moon	61.04%	46.63%	43.82%
	Proposed +Moon	76.66%	61.83%	57.97%
	Su	75.14%	63.11%	59.14%
	Proposed +Su	80.29%	67.77%	63.74%
	Wang	81.59%	71.27%	67.81%
	Proposed +Wang	83.8%	73.22%	69.71%
36	Moon	73.76%	65.75%	60.91%
	Proposed +Moon	86.16%	79.87%	74.31%
	Su	85.1%	80.11%	75.86%
	Proposed +Su	88.94%	84.06%	78.6%
	Wang	89.69%	85.88%	81.88%
	Proposed +Wang	91.34%	87.61%	83.65%
40	Moon	82.32%	78.88%	74.05%
	Proposed +Moon	92.67%	91.37%	86.84%
	Su	91.3%	89.5%	86.38%
	Proposed +Su	94.15%	93.25%	89.74%
	Wang	94.14%	93.41%	90.49%
	Proposed +Wang	95.39%	95.1%	92.15%

From Tables, we can find our proposed algorithm based on exiting AZBs detecting algorithms [6-9] can further increase DR about 10.04% ~ 18.83% on average. For example, the average DR increases15.05% more when compared with Moon's method in the lower QP =28 for all sequences. In M2 and M3 modes for Su's and Wang's methods, the proposed integrated algorithm can further increase the detecting ratio up to about 4.01% on average. In addition, we also find the detection ratios of AZBs using our method are well improved when QP is lower. On the other hand, we also find that the increasing DR is gradually reduced when the value of QP is increasing. From Table 4, we can find the DR is almost the same when QP=40 for all sequences. This is because the most coefficients after DCT/Q are quantized to zero as QP value is higher.

There are two parts in the total calculations of AZB detecting algorithm. One is the computation to determine AZBs. The other is the computation of the DCT/Q modules for non AZBs. Therefore, the coding time is proportional to the total calculations of AZB. To evaluate the time improving ration, we compare the coding time of the proposed method based on existing AZBs detecting methods with the original DCT/Q modules in JM software. The time improving ratio (TIR) is defined as

$$TIR = \frac{Time_{JM} - Time_{Proposed}}{Time_{JM}} \times 100\% \qquad (29)$$

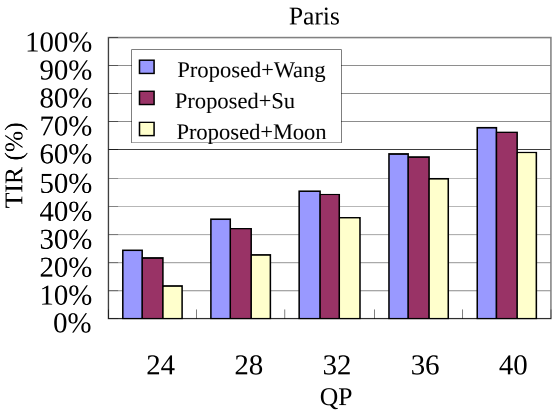
The average TIR using the proposed method based on different AZB detecting algorithms is shown in Fig. 3. Figures 3(a) and 3(b) show the TIR varying of the proposed method based on different AZB detecting algorithms as compared with JM 18.1 under different QPs, respectively. From Fig.3, we can observe that the encoding time improving is more efficient when the value of QP increases. Figures 3(a) and 3(b) show the DCT/Q processing time for Paris and Akiyo sequences tested by different methods with different QP values, respectively. As shown in Fig. 3(e) and 3(f), the proposed method can improve the DCT/Q encoding time under different QPs. However, the TIR of Akiyo sequence is more efficient than that of Paris sequence when the value of QP increases. This is because the content and move of Paris sequence are complex and fast in the more number of non-AZBs. From Fig.3, we can find the proposed algorithm achieves an average of 10% ~ 83% coding time saving than DCT/Q module in JM 18.1.

Table 4: Comparisons of the detection ratio using CIF.

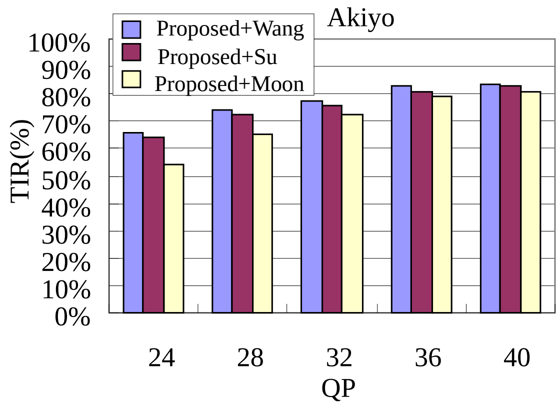
QP	Methods	Container	Paris	Akiyo
28	Moon	42.75%	41.83%	82.38%
	Proposed +Moon	57.53%	56.81%	90.26%
	Su	58.03%	56.38%	89.31%
	Proposed +Su	62.3%	60.88%	91.62%
	Wang	64.97%	63.13%	92.12%
	Proposed +Wang	66.69%	65.18%	92.98%
32	Moon	62.68%	53.18%	87.36%
	Proposed +Moon	72.89%	66.05%	92.74%
	Su	73.49%	66.2%	92.51%
	Proposed +Su	76.34%	69.81%	93.93%
	Wang	78.39%	71.98%	94.48%
	Proposed +Wang	79.47%	73.47%	95.05%
36	Moon	75.55%	65.02%	92.13%
	Proposed +Moon	81.52%	74.44%	95.59%
	Su	82.69%	75.19%	95.6%
	Proposed +Su	84.31%	77.6%	96.48%
	Wang	86.11%	79.61%	96.81%
	Proposed +Wang	86.67%	80.55%	97.19%
40	Moon	83.75%	73.25%	94.81%
	Proposed +Moon	88.78%	81.34%	97.64%
	Su	89.30%	81.79%	97.37%
	Proposed +Su	90.69%	83.87%	98.12%
	Wang	92.07%	85.62%	98.24%
	Proposed +Wang	92.61%	86.5%	98.55%

6. Conclusions

This work has proposed an efficient algorithm for early detecting AZB by combining energy conservation theorem and the SEA. A mathematical inequality is derived from Parseval theorem and applying SEA for motion estimation. Simulation results show that the proposed algorithm achieves approximately a 12% ~ 22% computational saving compared to the existing methods. Furthermore, when the proposed algorithm is implemented with other fast AZB detection algorithms, it can further improve AZB detection ratio without any video-quality degradation.



(a)



(b)

Figure 3: The average TIR using the proposed method based on different AZB detecting algorithms. (a) Paris (b) Akiyo.

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