Efficient Prediction Algorithm of Integer DCT Coefficients for H.264/AVC Optimization

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Abstract—This paper presents a novel efficient prediction algorithm to reduce redundant discrete cosine transform (DCT) and quantization computations for H.264 encoding optimization. A theoretical analysis is performed to study the sufficient condition for DCT coefficients to be quantized to zeros. As a result, three sufficient conditions corresponding to three types of transform and quantization methods in H.264 are proposed. Compared with other algorithms in the literature, the proposed algorithm derives more precise and efficient conditions to predict zero quantized DCT coefficients. Both the theoretical analysis and experimental results demonstrate that the proposed algorithm is superior to other algorithms in terms of the computational complexity reduction, encoded video quality, false acceptance rate, and false rejection rate.

Index Terms—H.264, integer DCT, quantization.

I. INTRODUCTION

THE recently developed video coding standard H.264/AVC [1] significantly outperforms previous standards such as MPEG-4 and H.263 in terms of coding efficiency. However, its computational complexity is too high to be widely applied in real-time applications. In general, mode selection and motion estimation contribute most of the complexity of H.264 video encoders. To improve the real time performance of H.264 video encoders, fast motion estimation and mode selection algorithms are proposed in recent years to speed up H.264 encoding. As the complexity of motion estimation and mode selection being reduced, we might also need to optimize other functions in order to further speed up the video encoding.

The discrete cosine transform (DCT) and quantization (Q) are the other two important functions in H.264 encoding which take up about 16% of the total computations in a digital signal processor (DSP)-based H.264 encoder [2]. In digital video coding, it is quite common that all the DCT coefficients in a block are quantized to zeros. In such a case, only a special symbol is sent to the decoder to indicate this all-zero state, and thus achieve high compression rate. However, this all-zero state can only be determined after DCT and Q. Therefore, considerable computations may be saved if there is a method that can early detect all-zero DCT blocks before implementing DCT and Q.

A number of early detection algorithms of all-zero DCT blocks have been studied for the $8 \times 8$ DCT-based video encoder such as [3]–[6]. However, those algorithms can not be directly applied to the H.264 encoder. The H.264 uses three transforms [7] depending on the type of residue data to be encoded: 1) an integer $4 \times 4$ DCT for all the $4 \times 4$ blocks in the residual data (Normal4 $\times$ 4 type); 2) a Hadamard transform for the $4 \times 4$ array of luma dc coefficients in intra $16 \times 16$ mode (LumaDC4 $\times$ 4 type); and 3) a Hadamard transform for the $2 \times 2$ array of chroma dc coefficients (ChromaDC2 $\times$ 2 type). In [8], after examining the properties of DCT and Q in H.264, Kim et al. propose a more precise sufficient condition to detect all-zero DCT blocks when compared with Sousa’s algorithm [5]. Unfortunately, only the Normal4 $\times$ 4 type is considered in [8] to detect all-zero DCT blocks, and the LumaDC4 $\times$ 4 type and ChromaDC2 $\times$ 2 type are not taken into account. Thus, the nonzero dc coefficients in both the LumaDC4 $\times$ 4 and ChromaDC2 $\times$ 2 types may be misclassified as zero-valued and the video quality will degrade as a consequence.

In this paper, the early detection of all-zero DCT blocks in H.264 is greatly improved. We have performed a comprehensive analysis of the dynamic range of DCT coefficients in the Normal4 $\times$ 4 type and derive a more precise sufficient condition than those of Sousa’s algorithm [5] and Kim’s algorithm [8] to detect all-zero DCT blocks. In addition, we also theoretically study the LumaDC4 $\times$ 4 and ChromaDC2 $\times$ 2 type and provide sufficient conditions under which the dc coefficients in these two types after Hadamard transform are quantized to zeros. As a result, the proposed algorithm can significantly reduce redundant DCT and Q computations without video quality degradation. The rest of this paper is organized as follows. The DCT and quantization adopted in H.264 are discussed in Section II. In Section III, the novel early detection algorithm is proposed and compared with other algorithms. Experimental results are presented in Section IV. Finally, Section V concludes this paper.

II. TRANSFORM AND QUANTIZATION IN H.264

Similar to previous video coding standards, H.264 utilizes transform coding of the prediction residue. However, in H.264, the transformation is applied to $4 \times 4$ blocks and three transforms are used depending on the type of residue data to be encoded: Normal4 $\times$ 4, LumaDC4 $\times$ 4, and ChromaDC2 $\times$ 2 [7].

A. Normal4 $\times$ 4 Type Transform and Quantization

The Normal4 $\times$ 4 transform is an integer transform and avoids inverse transform mismatch problems. The core part of this transform can be implemented using only additions and shifts in 16-bit integer arithmetic. And a scaling multiplication
is integrated into the quantiser to avoid divisions for quantization. For a $4 \times 4$ residual block $e(x,y)$, $0 \leq x,y \leq 3$, the integer transform can be defined as

$$E(u,v) = \sum_{x=0}^{3} \sum_{y=0}^{3} e(x,y) \cdot A(x,u) \cdot A(y,v) \quad (1)$$

where

$$A(m,n) = \frac{\langle 2.5C(n) \rangle}{\sqrt{2}} \cos \left( \frac{2m + 1}{8} \pi n \right) \quad (2)$$

where $C(n) = 1/\sqrt{2}$, for $n = 0$; and $C(n) = 1$, otherwise. The operator $\langle x \rangle$ denotes to round the operand $x$ to the nearest integer. Given an integer DCT coefficient $E(u,v)$ and a quantization parameter $Q_p$ ranging from 0 to 51, the quantized coefficient $Z(u,v)$, $0 \leq u,v \leq 3$, is written as

$$Z(u,v) = (\langle E(u,v) \rangle \cdot M(u,v) + f) \gg \text{qbits}$$

$$\text{sign}(Z(u,v)) = \text{sign}(E(u,v)) \quad (3)$$

where $\text{qbits} = 15 + \text{floor}(Q_p/6);$ $\gg$ indicates the binary shift right; $f$ is $\langle 2^{\text{qbits}/3} \rangle$ for intra-blocks or $\langle 2^{\text{qbits}/6} \rangle$ for inter-blocks. $M(u,v)$ is the multiplication factor related to $Q_p$%6, and three categories can be classified depending on the positions listed in Table I.

**B. LumaDC4 $\times$ 4 Type Transform and Quantization**

If the macroblock is encoded in Intra16 $\times$ 16 mode, each $4 \times 4$ residual block is first transformed using the Normal4 $\times$ 4 type as described above. Then the dc coefficient of each $4 \times 4$ block is transformed again using a $4 \times 4$ Hadamard transform as

$$Y_4 = \frac{H_4 E_4 H_4^T}{2} \quad (4)$$

and

$$H_4 = \begin{bmatrix}
1 & 1 & 1 & 1 \\
1 & 1 & -1 & -1 \\
1 & -1 & -1 & 1 \\
1 & -1 & 1 & -1
\end{bmatrix} \quad (5)$$

$E_4$ is the block of $4 \times 4$ dc coefficients and $Y_4$ is the block after transformation. Then the quantized dc coefficient is obtained by

$$Z_4(u,v) = (\langle Y_4(u,v) \rangle \cdot M(0,0) + 2f) \gg \text{qbits} + 1$$

$$\text{sign}(Z_4(u,v)) = \text{sign}(Y_4(u,v)) \quad (6)$$

**C. ChromaDC2 $\times$ 2 Type Transform and Quantization**

The $4 \times 4$ chroma blocks are transformed using the Normal4 $\times$ 4 type. Then the dc coefficients of each $4 \times 4$ block of chroma coefficients are grouped in a $2 \times 2$ block $E_2$ and are further transformed using a $2 \times 2$ Hadamard transform as

$$Y_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} E_2 \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (7)$$

Quantization of the $2 \times 2$ output block $Y_2$ is performed by

$$Z_2(u,v) = (\langle Y_2(u,v) \rangle \cdot M(0,0) + 2f) \gg \text{qbits} + 1$$

$$\text{sign}(Z_2(u,v)) = \text{sign}(Y_2(u,v)) \quad (8)$$

**III. PROPOSED ALGORITHM**

**A. Prediction of All-Zero DCT Blocks in Normal4 $\times$ 4 Type**

In the Normal4 $\times$ 4 type, the sufficient condition under which the DCT coefficient $E(u,v)$ is quantized to zero is given as

$$|E(u,v)| < T(u,v), \quad T(u,v) = \frac{2^{\text{qbits}} - f}{M(u,v)} \quad (9)$$

From (1), we can derive

$$|E(u,v)| \leq \sum_{x=0}^{3} \sum_{y=0}^{3} |e(x,y)| \cdot |A(x,u)| \cdot |A(y,v)| \geq B(u,v) \quad (10)$$

where $B(u,v)$ can be written as

$$B(u,v) = \sum_{x=0}^{3} \sum_{y=0}^{3} E_{al} \otimes A_{al}(u,v) \quad (11)$$

where $E_{al} = [e(x,y)]_{4 \times 4}$. $A_{al}(u,v) = [A(x,u)], [A(y,v)]_{4 \times 4}$, and $\otimes$ indicates that each element of $E_{al}$ is multiplied by the element in the same position in matrix $A_{al}(u,v)$.

Sufficient conditions for each DCT coefficient to be quantized to zero can be obtained by studying the property of $B$. The case of $u = v = 1$ is firstly analyzed, such as

$$A_{al}(1,1) = \begin{bmatrix}
4 & 2 & 2 & 4 \\
2 & 1 & 1 & 2 \\
2 & 1 & 1 & 2 \\
4 & 2 & 2 & 4
\end{bmatrix} \quad (12)$$
To simplify discussion without loss of generality, a $4 \times 4$ block is divided into four regions: $A_1$, $A_2$, $A_3$, and $A_4$, such as

\[
A_1 = \{(x, y) | x = 0, 3, y = 0, 3\}
\]

\[
A_2 = \{(x, y) | x = 0, 3, y = 1, 2\}
\]

\[
A_3 = \{(x, y) | x = 1, 2, y = 1, 2\}
\]

\[
A_4 = \{(x, y) | x = 1, 2, y = 0, 3\},
\]

(13)

The sum of absolute difference (SAD) $S_i$ for each region $A_i$, $1 \leq i \leq 4$, can be written as

\[
S_i = \sum_x \sum_y |e(x, y)|, \quad \forall (x, y) \in A_i, 1 \leq i \leq 4.
\]

(14)

And the SAD of a $4 \times 4$ block is $SAD = \sum_{i=1}^{4} S_i$. Therefore, considering (11)–(14), we have

\[
B(1, 1) = 2SAD + 2S_1 - S_3.
\]

(15)

From (9) and (10), the sufficient condition to detect zero quantized DCT coefficients can be given as

\[
B(u, v) < T(u, v).
\]

(16)

Thus, the final sufficient condition for DCT coefficient in (1, 1) to be zero after quantization is

\[
SAD < \frac{T(1, 1)}{2} + \frac{S_3 - 2S_1}{2}.
\]

(17)

Similarly, the sufficient conditions for other positions are calculated and listed in Table II. According to the three categories in Table I, three thresholds $T_h$, $1 \leq i \leq 3$, can be derived from Table II to detect all-zero DCT coefficients in each category. The thresholds $T_h$ are defined as

\[
T_h = \frac{T(1, 1)}{2} + \frac{1}{2} \times \min \{S_3 - 2S_1, S_4 - 2S_2, S_2 - 2S_1, S_1 - 2S_3\}.
\]

(18)

\[
T_h = \frac{T(0, 1)}{2} + \frac{1}{2} \times \min \{S_2 + S_3, S_1 + S_4, S_3 + S_4, S_1 + S_2\}.
\]

(19)

\[
T_3 = T(0, 0)
\]

(20)

If $SAD < T_h$, then all the DCT coefficients in the $i$th category (Table I) will be quantized to zeros. Therefore, we derive the sufficient condition given by

\[
SAD < TS, \quad TS \triangleq \min \{T_h, T_h, T_3\}
\]

(21)

under which all the DCT coefficients in a $4 \times 4$ block will be quantized to zeros.

### Table II

<table>
<thead>
<tr>
<th>Condition</th>
<th>Position $(u, v)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SAD &lt; \frac{T(1, 1) + S_3 - 2S_1}{2}$</td>
<td>$(1, 1)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(1, 1) + S_4 - 2S_2}{2}$</td>
<td>$(1, 3)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(1, 1) + S_2 - 2S_1}{2}$</td>
<td>$(3, 1)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(1, 1) + S_2 - 2S_1}{2}$</td>
<td>$(3, 3)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(0, 1) + S_3 + S_4}{2}$</td>
<td>$(0, 1)(2, 1)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(0, 1) + S_4 + S_3}{2}$</td>
<td>$(0, 3)(2, 3)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(0, 1) + S_1 + S_4}{2}$</td>
<td>$(1, 0)(1, 2)$</td>
</tr>
<tr>
<td>$SAD &lt; \frac{T(0, 1) + S_1 + S_4}{2}$</td>
<td>$(3, 0)(3, 2)$</td>
</tr>
<tr>
<td>$SAD &lt; T(0, 0)$</td>
<td>$(0, 0)(0, 2)(2, 0)(2, 2)$</td>
</tr>
</tbody>
</table>

### B. Prediction in LumaDC4 $\times$ 4 and ChromaDC2 $\times$ 2 Type

In the LumaDC4 $\times$ 4 and ChromaDC2 $\times$ 2 type, the dc coefficients after $4 \times 4$ DCT transform undergo another Hadamard transform and are quantized differently compared with the Normal4 $\times$ 4 type. Thus, under the condition in (21), the quantized dc coefficients are not guaranteed to be zeros. In the LumaDC4 $\times$ 4 type, the quantized dc coefficient $Z_4(u, v)$ in (6) is zero if

\[
|Y_4(u, v)| < 2 \cdot \frac{2^{\text{shifts}} - f}{M(0, 0)} = 2T_h3.
\]

(22)

After analyzing (4) and (5), we can obtain

\[
|Y_4(u, v)| \leq \frac{1}{2} \sum_{i=0}^{3} \sum_{j=0}^{3} |E_4(i, j)|, \quad 0 \leq u, v \leq 3
\]

(23)

where $E_4(i, j)$ is the dc coefficient of the $(i, j)$th $4 \times 4$ block in a macroblock. Given the SAD$(i, j)$ as the SAD value of the $(i, j)$th $4 \times 4$ block, according to (10), we have

\[
|E_4(i, j)| \leq \text{SAD}(i, j).
\]

(24)

After substituting (24) into (23), we obtain

\[
|Y_4(u, v)| \leq \frac{1}{2} \sum_{i=0}^{3} \sum_{j=0}^{3} \text{SAD}(i, j) = \frac{1}{2} \text{SAD}_{16}
\]

(25)

where SAD$_{16}$ is the SAD of a $16 \times 16$ macroblock. Combing (22) and (25), we can derive the sufficient condition as

\[
\text{SAD}_{16} < 4T_h3
\]

(26)

under which all the dc coefficients in the LumaDC4 $\times$ 4 type are quantized to zeros. In a similar manner, we can derive the sufficient condition for the ChromaDC2 $\times$ 2 type as

\[
\text{SAD}_{16} < 4T_h3
\]

(27)

where SAD$_{16}$ is the SAD of an $8 \times 8$ chroma block.
C. Proposed Algorithm for H.264 Optimization

Based on the above analysis, we propose the following algorithm to reduce redundant DCT, Q, inverse Q (IQ), and inverse DCT (IDCT) computations for H.264 encoding optimization.

Step 1) If the current macroblock is encoded in Intra16 × 16 mode, go to step 2. Else go to step 4.

Step 2) If SAD_{16} < 4T h_3, f_{16} = 1, else f_{16} = 0. Go to step 3.

Step 3) For luma blocks, if SAD < TS and f_{16} = 1, DCT, Q, IQ, IDCT are not performed. Else if SAD < TS and f_{16} = 0, DCT, Q, IQ, IDCT are only performed to DC coefficients. Else if SAD ≥ TS and f_{16} = 1, DCT, Q, IQ, IDCT are only performed to AC coefficients. Else, DCT, Q, IQ, IDCT are performed to all the AC coefficients. Go to step 5.

Step 4) For luma blocks, if SAD < TS, DCT, Q, IQ, IDCT are skipped. Else, DCT, Q, IQ, IDCT are performed to all the AC coefficients. Go to step 5.

Step 5) If SAD_{4c} < 2T h_3, f_{c} = 1, else f_{c} = 0. Go to step 6.

Step 6) For chroma blocks, if SAD < TS and f_{c} = 1, DCT, Q, IQ, IDCT are not performed. Else if SAD < TS and f_{c} = 0, DCT, Q, IQ, IDCT are only performed to DC coefficients. Else if SAD ≥ TS and f_{c} = 1, DCT, Q, IQ, IDCT are only performed to AC coefficients. Else, DCT, Q, IQ, IDCT are performed to all the AC coefficients.

D. Comparison With Other Algorithms

If Sousa’s algorithm [5] is applied, the sufficient condition to detect all-zero DCT blocks is

\[
\text{SAD} < T S^s, \quad T S^s \triangleq \frac{T (1,1)}{4}.
\]  (28)

In [8], Kim et al. refine Sousa’s algorithm and propose the sufficient condition as

\[
\text{SAD} < T S^k, \quad T S^k \triangleq \min \left\{ T \frac{1}{4}, \frac{T (0,1)}{2} \right\}
\]  (29)

where

\[
T \frac{1}{4} = \frac{T (1,1)}{4} + \frac{\min \{ S_1 + S_2, S_3 + S_4 \}}{2}.
\]  (30)

In our algorithm, after some modifications, we can rewrite the threshold \( T h_3 \) in (18) as

\[
T h_3 = \frac{T (1,1)}{4} + \frac{1}{4} \min \{ 2S_2 + 3S_3 + 2S_4, 3S_1 + 2S_3 + 3S_4, 2S_1 + 3S_2 + 2S_3, 3S_1 + 2S_2 + 2S_4 \}.
\]  (31)

We can easily prove \( T h_1 \geq T h_k \), \( T h_2 \geq T (0,1)/2 \), and \( T (0,0) > T (0,1)/2 > T (1,1)/4 \). Therefore, we can derive

\[
T S \geq T S^k \geq T S^s.
\]  (32)

As a result, our proposed algorithm provides a more efficient condition to detect all-zero DCT blocks than [5] and [8]. In addition, we also derive two sufficient conditions in (26) and (27) to detect zero DC coefficients for the LumaDC4 × 4 and ChromaDC2 × 2 type, which are not considered in [5] and [8]. Hence, our algorithm is more effective and precise.

IV. EXPERIMENTAL RESULTS

The recent H.264 reference software JM9.5 [9] is performed to evaluate the proposed algorithm. The fast motion estimation is enabled and the number of reference frames is set to 1. All the block search sizes are enabled for mode selection. To examine the effectiveness of the proposed algorithm in different experimental conditions, several benchmark video sequences with different motion activities are used, which are in CIF format (352 × 288) and have 100 frames to be encoded. In addition, in order to examine the performance at different bit rates, five \( Q_p \) values: 24, 28, 32, 36, and 40, are used in our experiments. For comparison, the algorithms discussed in [5] and [8] are implemented.

The computational complexity reduction of DCT, Q, IQ, and IDCT are evaluated in the following two conditions: 1) under condition 1, the fast algorithms including [5], [8] and the proposed algorithm are only performed in the Normal4 × 4 type and skipped in the LumaDC4 × 4 and ChromaDC2 × 2 type and 2) the fast algorithms are performed to all the three DCT and quantization types under condition 2. Under both of these two conditions, the computation reduction is assessed as

\[
\Delta T = \frac{T_{org} - T}{T_{org}} \times 100\%.
\]  (33)

where \( T \) is the encoding time of DCT, Q, IQ, and IDCT for each algorithm and \( T_{org} \) is the encoding time consumed by DCT, Q, IQ, and IDCT in the original encoder. The results are shown in Table III. It is evident in Table III that the proposed algorithm can achieve the best performance in reducing the computational complexity of DCT, Q, IQ, and IDCT than [5] and [8] under both
of the two conditions. It reveals that the proposed algorithm provides a more efficient threshold \( T_{H1} \) in (18) than [5] and [8] to detect all-zero DCT blocks under condition 1. As far as condition 2 is concerned, more calculations are reduced when the proposed algorithm is applied to all the three DCT types compared with condition 1 indicating that applying early detection in the LumaDC4 × 4 and ChromaDC2 × 2 type is useful to reduce redundant computations.

The encoded video quality is evaluated in terms of the peak signal-to-noise ratio (PSNR). Under condition 1, all the three algorithms provide sufficient conditions to detect all-zero DCT blocks in the Normal4 × 4 type, hence, no PSNR drop is observed for all the test algorithms. The average PSNR degradation \( \Delta P \) between the test algorithm and the original encoder under condition 2 are shown in Table IV. Note that the proposed algorithm will not degrade video quality as expected, because it provides more precise analysis of the zero quantized DCT coefficients and considers all the transform and quantization types. Since the algorithms [5] and [8] do not consider the LumaDC4 × 4 and ChromaDC2 × 2 type, therefore several nonzero quantized dc coefficients may be misclassified as zero-valued. Thus, the encoded video quality deteriorates as observed in Table IV.

The false rejection rate (FRR) and false acceptance rate (FAR) are provided to compare the prediction capacity of zero ac coefficient blocks and zero dc coefficients for the proposed algorithm and the algorithms in [5] and [8]. The smaller the FRR is, the more efficiently the algorithm can detect zero ac coefficient blocks or zero dc coefficients. The smaller the FAR is, the less the video quality degrades. Thus, it is more desirable to have small FAR and FRR values for efficient prediction algorithms. Due to the space limit, we only present the FRR and FAR results under condition 2 for the Foreman and News sequence. The FRR and FAR results under condition 1 and for other benchmark sequences are consistent with the results presented herein.

Since the proposed algorithm and the algorithms in [5] and [8] provides sufficient conditions to detect zero ac coefficient blocks, the FAR values of zero ac coefficient blocks for these three algorithms should be zero-valued and have been verified from the experimental results. The comparative results of FRR of zero ac coefficient blocks are illustrated in Figs. 1 and 2, where we can see that our algorithm is superior to the other two algorithms because the proposed algorithm derives the optimal threshold to early detect zero ac blocks. The results of FRR and FAR of zero dc coefficients are illustrated in Figs. 3–6. In all the cases, the thresholds provided by our algorithm can predict more zero dc coefficients than those of the algorithms in [5] and [8], thus smaller FAR values are achieved by our algorithm as shown in Figs. 3 and 4. From the FAR results of zero dc coefficients in Figs. 5 and 6, the proposed algorithm can achieve zero FAR values as expected, since accurate sufficient conditions are derived for detection of zero dc coefficients in the LumaDC4 ×

<table>
<thead>
<tr>
<th>( Q_p )</th>
<th>Foreman</th>
<th>News</th>
<th>( Q_p )</th>
<th>Foreman</th>
<th>News</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>-0.020</td>
<td>-0.054</td>
<td>-0.013</td>
<td>-0.055</td>
<td>-0.015</td>
</tr>
<tr>
<td>28</td>
<td>-0.022</td>
<td>-0.055</td>
<td>-0.044</td>
<td>-0.118</td>
<td>-0.015</td>
</tr>
<tr>
<td>32</td>
<td>-0.018</td>
<td>-0.075</td>
<td>-0.049</td>
<td>-0.115</td>
<td>-0.015</td>
</tr>
<tr>
<td>36</td>
<td>-0.063</td>
<td>-0.127</td>
<td>-0.122</td>
<td>-0.189</td>
<td>-0.015</td>
</tr>
<tr>
<td>40</td>
<td>-0.068</td>
<td>-0.165</td>
<td>-0.128</td>
<td>-0.319</td>
<td>-0.015</td>
</tr>
</tbody>
</table>

Fig. 1. FRR of zero ac coefficient blocks, Foreman.

Fig. 2. FRR of zero ac coefficient blocks, News.

Fig. 3. FRR of zero dc coefficients, Foreman.
from these two algorithms. This also explains why video quality degrades when applying these two algorithms under condition 2.

In addition, we also test the proposed algorithm by setting the number of motion estimation reference frames equal to 5. The experimental results are observed similar to the results presented above. This indicates that the performance of the proposed algorithm does not depend on the number of reference frames. Generally speaking, because the proposed algorithm is proved based on strict theoretical analysis and focused on the computational complexity reduction of DCT, Q, IQ, and IDCT functions, it can be applied with any of fast motion estimation and mode decision algorithms which use SAD as the matching criteria.

V. Conclusion

In this paper, an efficient algorithm is proposed to early detect zero quantized DCT coefficients for H.264 encoding optimization. We perform a theoretical analysis of the dynamic range of DCT coefficients in the Normal4 \( \times 4 \) type, and derive a more effective condition than [5] and [8] to reduce DCT and Q computations. In addition, the LumaDC4 \( \times 4 \) and ChromaDC2 \( \times 2 \) type are theoretically studied and two precise sufficient conditions are derived to predict zero quantized dc coefficients. As a result, the proposed algorithm can significantly reduce redundant DCT and Q computations without video quality degradation. The recent H.264 reference software JM9.5 is applied to evaluate the performance of the proposed algorithm. The experimental results demonstrate that the proposed algorithm outperforms the other two algorithms [5] and [8] in terms of the computational complexity reduction, encoded video quality, false acceptance rate and false rejection rate.

References