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# An Efficient Intra Skip Decision Algorithm for H.264/AVC Video Coding

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## Abstract

In this study, we propose a simple, highly efficient intra skip decision algorithm to reduce the computational complexity of H.264/AVC coding. It utilizes information such as the best mode and the rate value of the RD cost function, which are all pre-calculated. These values are calculated in the corresponding macroblock (MB) of the previous frame and the neighbouring MBs of the current frame in order to develop an intra skip decision rule. Our experimental results demonstrated that without the additional time-consuming computation, the proposed algorithm reduces encoding time by approximately 50% compared with the time needed for an exhaustive search and it significantly increases the time saving by 17%–30% compared with the existing algorithms. In addition, our experimental results showed that the differences in peak signal-to-noise ratio degradation are negligible and the bit rate increment is minimal.

***Key Words***: H.264/AVC, Video Coding, Intra Skip, Rate-Distortion Optimization (RDO)

## 1. Introduction

The H.264/advanced video coding (AVC) standard [1], also known as MPEG-4 Part-10 AVC, was developed by the Joint Video Team (JVT). JVT is a group of video coding experts from the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG). The video encoder in H.264/AVC consists of a number of coding tools, as it is shown in Figure 1. Most of the basic functional elements are present in previous standards (MPEG-2, MPEG-4, H.263), but the important changes in H.264 occur in the details of each functional block [21].

To improve the coding efficiency in terms of both peak signal-to-noise ratio (PSNR) and visual quality while operating at the same bit rate as prior video coding standards, the H.264/AVC adopts a number of advanced coding tools, such as variable block sizes, multiple reference frames, multiple intra prediction modes and rate-distortion optimization (RDO) [2]. Although the coding tools of H.264/AVC can save up to 39%, 49% and 64% of the bit rate compared with MPEG-4, H.263 and MPEG-2, respectively [2], they significantly increase the computational complexity [3,4]. In H.264/AVC encoder, the exhaustive search method (try all and select the best) costs extremely high computational complexity and limit the usefulness of the real application. Therefore, reducing the computational complexity and preserving the video quality and bit rate as close as possible to those of an exhaustive search by developing fast algorithms has become the main subject for practical H.264/AVC coding.

In this study, we propose a simple, highly efficient intra skip decision algorithm to reduce the computational complexity. The rest of this paper is organized as follows. Section 2 highlights the related works. Section 3 describes our observations and analysis, and presents the proposed efficient intra skip decision algorithm. Section 4 presents the experimental results. Finally, section 5 concludes the paper.

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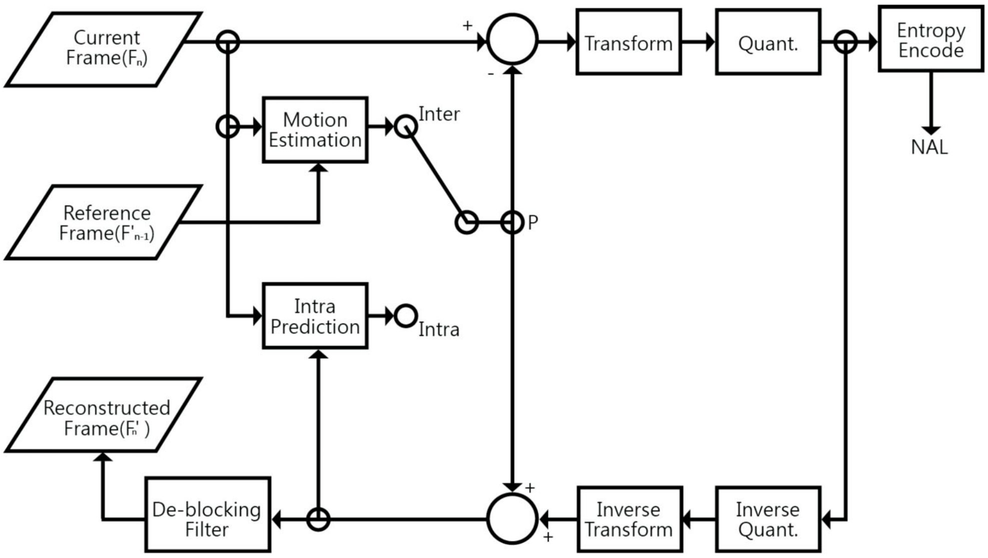


**Figure 1.** H.264 encoder block diagram.

## 2. Related Works

In the literature, many methods have been presented to develop fast algorithms for the H.264/AVC. In general, fast algorithms for the H.264/AVC can be classified into two categories. One category includes fast inter mode motion estimations [5−7] that intend to reduce the number of search points in the inter frame encoding. The other category includes fast intra mode predictions [8−10] that intend to reduce the number of prediction modes to be checked in the intra frame encoding. An additional technique, which has not been categorized, uses intra skip in the inter frame encoding. Normally, the inter mode encoding is followed by the intra mode encoding in inter frames. However, the intra mode is rarely selected as the best mode for the inter frames, i.e. the average probability is typically less than 5%. Therefore, several researchers have recently presented intra skip decision algorithms to reduce the computational complexity [11−16].

In particular, Choi et al. [11] proposed an algorithm that uses the boundary difference between the pixels at the boundary of the current macroblock (MB) and its adjacent upper and left encoded blocks as the degree of spatial correlation and the average number of bits consumed to encode the motion-compensated residual data as the degree of temporal correlation. If the degree of temporal correlation is less than the degree of spatial correlation, the algorithm skips the intra mode search. Kim [12] presented the minimum RD cost of the neighbouring MBs as an adaptive threshold that is compared with the sum of absolute differences (SAD) of the best inter mode. In Kim's algorithm, if the adaptive threshold is greater than or equal to the SAD, then the intra mode search is skipped.

Lee et al. [13] proposed an algorithm that uses the information of the histogram difference to measure the similarity of two adjacent frames and fuzzy logic to determine whether the intra coding mode can be skipped. Kim et al. [14] presented an algorithm that uses an adaptive motion vector map to store complex or simple areas determined by the absolute sum of the motion vectors, followed by the comparison of the best inter RD cost and the average RD cost of I4MB and SUB8x8 of the previous frame to filter out intra mode prediction.

In addition, Kim et al. [15] presented an intra skip decision process based on the motion homogeneity calculated from the mean deviation of motion vectors, the temporal homogeneity computed from the SAD difference between the current MB and predictive MB and the spatial homogeneity calculated from the SAD difference between the current MB and predictive INTRA_16x16 MB. Huang et al. [16] proposed that the difference between the RD cost of the best inter mode and the cost of I16MB can be used to determine whether the intra coding mode can be skipped.

## 3. Efficient Intra Skip Decision Algorithm for H.264/AVC Video Coding

### 3.1 Observations and Analysis

In the coding tools of the H.264/AVC, there exist two types of prediction modes: inter mode prediction and intra mode prediction. Inter mode prediction creates a prediction model from one or more previously encoded video frames by using block-based motion compensation, whereas intra mode prediction is based on previously encoded and reconstructed blocks of the same frame. The first frame of an H.264/AVC video sequence has to be encoded using intra mode prediction, but subsequent frames can be encoded using either inter mode prediction or intra mode prediction. According to the normal procedure in the JVT reference software (version JM13.2) [17], inter mode coding is followed by intra mode coding. In real video sequences, intra mode is seldom selected as the best mode for coding. We use the JM13.2 reference software with exhaustive search capabilities to analyse the occupation percentage of the intra MB modes in inter frames.

Figure 2 shows the results obtained using various quantisation parameters ($QP = 20, 24, 28, 32$), six video test sequences (Carphone, Silent, Table Tennis, Parkrun, Shields and Foreman) and 100 frames for each video test sequence. The occupancy of the most intra MB is only 1%–5%, except the 'Shields' at low *QP* value. The 'Shields' is a complex and whole picture moving fast high-definition (HD) video, which cause higher intra MB percentage, but it dose not effect our further experiment.

Obviously, the intra MBs occupy only a small percentage of the inter frames. Therefore, a large amount of computation is wasted because all MBs must be examined by the intra mode prediction process. These results highlight the need for a fast algorithm that can reduce the computational redundancies while keeping the visual quality and bit rate as close as possible to those obtained using an exhaustive search. Furthermore, we analyzed the specific conditions that allowed the intra mode prediction process is completely skipped due to only a small percentage of the resulting optimal modes are intra modes. Table 1 shows the results of skipping the entire processing of intra modes and compares the coding performance with that of an exhaustive search.

For the tests shown in Table 1, we used Bjontegaard delta *PSNR* (*BDPSNR*) and Bjontegaard delta bit rate (*BDBR*) [18] as the measuring tools and defined $\Delta PSNR$ and $\Delta BR$ as follows:

$$\Delta PSNR = PSNR_{\text{SkipIntraInInter}} - PSNR_{\text{ref}} \quad (1)$$

$$\Delta BR = \frac{BR_{\text{SkipIntraInInter}} - BR_{\text{ref}}}{BR_{\text{ref}}} \times 100(\%) \quad (2)$$

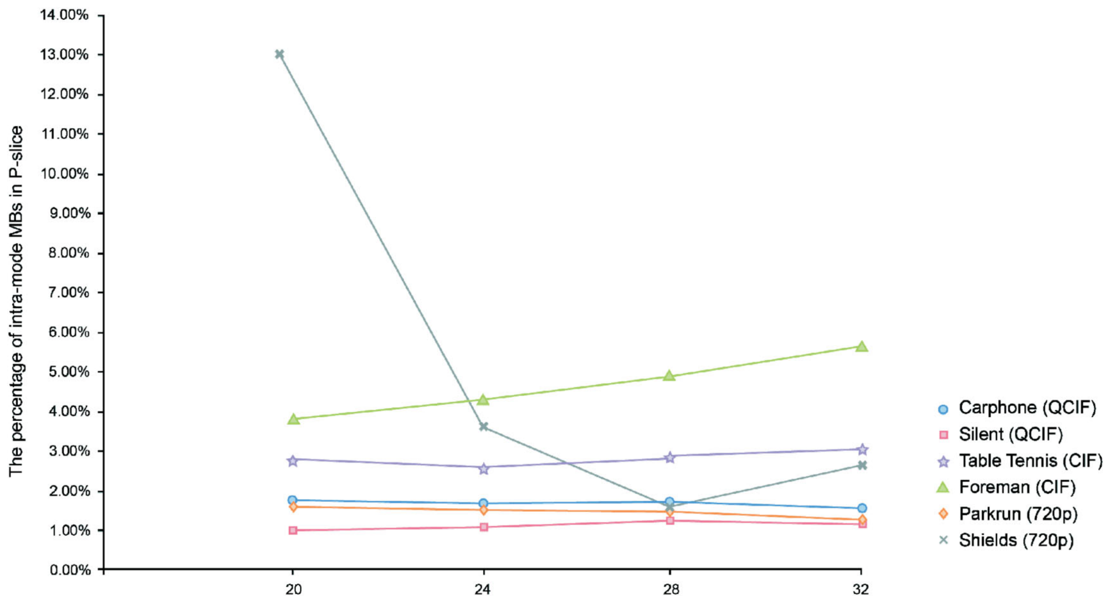


**Figure 2.** Percentage of the P-slice occupied by intra MBs.

where $PSNR_{\text{SkipIntraInInter}}$ and $BR_{\text{SkipIntraInInter}}$ are the performances of all intra skips in JM13.2, and $PSNR_{\text{ref}}$ and $BR_{\text{ref}}$ are the performances of an exhaustive search in JM13.2.

Note that in Table 1, the positive values for $\Delta PSNR$ indicate video quality improved, while negative values indicate video quality degraded; the positive values for $\Delta BR$ indicate the bit rate increment while the negative values indicate the bit rate decrement. In this table, the bit rate of each test sequence increased dramatically; for example, the bit rate of test sequence 'Table Tennis' increased up to approximately 7%. Certain factors caused these changes, such as a scene change, a light condition change or a new object appeared or was moving fast. Because of these changes, the MB under processing could not find a similar block in previous frames within the search range. In contrast, the *PSNR* values in Table 1 decreased slightly compared with the values resulting from an exhaustive search. On the basis of these results, we exploited this feature of the rate value of the RD cost function [19,20].

To achieve the best coding performance, the joint mode (JM) of the H.264/AVC reference software adopts the RDO technique. The RD cost function in the H.264/AVC is defined as follows:

$$J(s, c, MODE|QP) = SSD(s, c, MODE|QP) + \lambda_{MODE} \cdot R(s, c, MODE|QP) \quad (3)$$

where *QP* is the quantisation parameter, *SSD* denotes the sum of the squared difference between *s* and *c*, which is the distortion metric, *s* and *c* indicate the original block and its reconstructed block, respectively, *MODE* denotes an MB mode, λ is a Lagrange multiplier that weights the influence of both distortion and bit rate in the RD cost function and *R* represents the number of bits associated with the currently selected MB mode *MODE*.

Based on the above observation, we first used the rate value (i.e. R(s, c, MODE|QP)) of the corresponding MB of the previous frame as an adaptive threshold. According to the results in Table 1, the impact of the PSNR is slight when the entire intra coding process is skipped; therefore, we used the rate value instead of the RD cost as the adaptive threshold. If the rate value of the best inter mode of the current MB is less than or equal to the rate value of the corresponding MB of the previous frame, then the process skips the intra mode search. This is because if the cost of the current MB is sufficiently small, it can be considered that the cost of the best inter mode is good enough and the probability of the intra mode being the optimal best mode is low, and hence, it is not necessary to perform the intra mode prediction process.

To verify this scheme, we use two QCIF (176 × 144) video sequences, two CIF (352 × 288) video sequences, and two high resolution (1280 × 720) video sequences to make experiments. Table 2 shows the results of the averages of the six test sequences, where HR (%) and Skip (%) represent the percentage of the hit rate and skip rate, respectively. The hit rate indicates that the accuracy ratio of the best mode selected using the rate value as an adaptive threshold is the same as that of the best mode selected using an exhaustive search.

**Table 1.** Skipping all intra MBs in the inter slice

| Test sequence | *QP* | Δ*PSNR* (dB) | Δ*BR* (%) |
|---|---|---|---|
| Carphone (QCIF) | 20 | -0.021 | 0.345 |
| | 24 | -0.011 | -0.125 |
| | 28 | -0.025 | -0.236 |
| | 32 | -0.104 | 0.424 |
| Silent (QCIF) | 20 | 0.038 | 1.005 |
| | 24 | 0.025 | 0.971 |
| | 28 | 0.009 | 1.147 |
| | 32 | -0.030 | 0.958 |
| Table Tennis (CIF) | 20 | -0.015 | 2.956 |
| | 24 | -0.017 | 4.351 |
| | 28 | -0.045 | 4.103 |
| | 32 | -0.093 | 6.891 |
| Foreman (CIF) | 20 | -0.018 | 0.914 |
| | 24 | -0.017 | 0.801 |
| | 28 | -0.025 | 1.181 |
| | 32 | -0.092 | 1.185 |
| Parkrun (720p) | 20 | -0.002 | 0.170 |
| | 24 | 0.004 | 0.429 |
| | 28 | 0.004 | 0.412 |
| | 32 | 0.010 | 0.611 |
| Shields (720p) | 20 | 0.019 | 1.249 |
| | 24 | -0.003 | 1.158 |
| | 28 | -0.016 | 2.914 |
| | 32 | -0.049 | 5.234 |
| Average | | -0.020 | 1.627 |

As shown in Table 2, the average hit rate reached 99.35%, which proved that the rate value of the corresponding MB of the previous frame can be used as an appropriate adaptive threshold. In addition, the average skip rate reached 56.41%, which should be very close to the time saving ratio, because there is no additional time-consuming computation.

We examine the RD performance by applying the rate value of the corresponding MB of the previous frame as an adaptive threshold. Table 3 compares the results with those of an exhaustive search. In this table, $\Delta PSNR$ and $\Delta BR$, are defined as follows:

$$\Delta PSNR = PSNR_{\text{pro}} - PSNR_{\text{ref}} \quad (4)$$

$$\Delta BR = \frac{BR_{\text{pro}} - BR_{\text{ref}}}{BR_{\text{ref}}} \times 100(\%) \quad (5)$$

where $PSNR_{\text{pro}}$ and $BR_{\text{pro}}$ denote the $PSNR$ and the bit rate which applied an adaptive threshold algorithm, respectively; $PSNR_{\text{ref}}$ and $BR_{\text{ref}}$ denote the PSNR of the reference software and the bit rate of the reference software, respectively.

The positive value for $\Delta PSNR$ indicates the quality by applying an adaptive threshold algorithm is better than applying the reference software, and negative $\Delta BR$ indicates the bit rate by applying an adaptive threshold algorithm is better than the applying reference software. As shown in Table 3, the PSNR degraded by 0.005 dB on an average, which is better than that in the case of skipping all MBs (-0.020 dB in Table 1). And, the bit rate increased by 0.154% on an average, which is much lower than that in the case of skipping all MBs (1.627% in Table 1). It must be noted that the bit rates of the 'Carphone' and 'Shields' test sequences are smaller than that using an exhaustive search.

**Table 2.** Probability of the hit rate and skip rate using adaptive thresholds

| Test sequence | HR (%) | Skip (%) |
|---|---|---|
| Carphone (QCIF) | 99.50 | 55.52 |
| Silent (QCIF) | 99.82 | 65.91 |
| Table Tennis (CIF) | 99.02 | 55.19 |
| Foreman (CIF) | 99.29 | 54.92 |
| Parkrun (720p) | 99.89 | 52.37 |
| Shields (720p) | 98.57 | 54.54 |
| Average | 99.35 | 56.41 |

**Table 3.** RD performance using an adaptive threshold

| Test sequence | $\Delta PSNR$ (dB) | $\Delta BR$ (%) |
|---|---|---|
| Carphone (QCIF) | -0.003 | -0.036 |
| Silent (QCIF) | 0.002 | 0.116 |
| Table Tennis (CIF) | -0.014 | 0.363 |
| Foreman (CIF) | -0.006 | 0.101 |
| Parkrun (720p) | 0.001 | 0.038 |
| Shields (720p) | -0.012 | -0.016 |
| Average | -0.005 | 0.154 |

Furthermore, the $PSNR$ and the hit rate can be improved if we add some restrictions. We analysed the probability that the corresponding MB of the previous frame is an optimal intra mode so that the best mode of the MB under processing is the resulting optimal intra mode, and the probability that the upper or left MB of the current frame is an optimal intra mode so that the best mode of the MB under processing is the resulting optimal intra mode.

Figures 3(a) and (b) show the 89th and 90th frame of the CIF-size 'Foreman' test sequence, which is encoded using an exhaustive search with $QP = 28$. The white and red boxes in Figure 3 indicate the resulting optimal inter mode and intra mode, respectively. Figure 3(b) illustrates that many corresponding MBs of the previous frame or the upper or left MB of the current frame are intra mode coded, whereas the current MB is intra mode coded. This is because complex regions, such as the face region in the middle of Figure 3, or the sudden appearance of an object, such as the hand in the lower right of Figure 3, result in an optimal intra mode. Table 4 shows the probability that the corresponding MB of the previous frame is an optimal intra mode so that the best mode of the MB under processing is the resulting optimal intra mode. Table 5 shows the probability that the upper or left

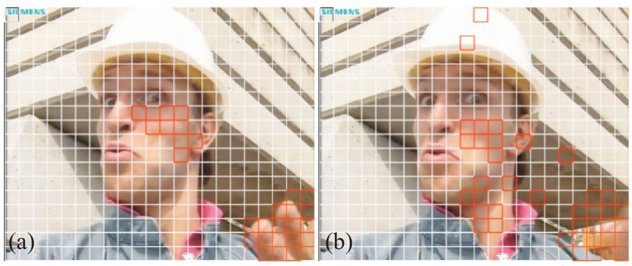

**Figure 3.** CIF-format of the 'Foreman' test sequence. (a) 89th frame. (b) 90th frame.

MB of the current frame is an optimal intra mode so that the best mode of the MB under processing is the resulting optimal intra mode.

Tables 4 and 5 show a high probability for both situations — from 1.97% to 74.00%. Therefore, according to the above analysis, we added an additional rule: if the corresponding MB of the previous frame or the upper or left MB of the current frame is the optimal intra mode, then the process does not intra skip. Table 6 shows the results after adding this rule. Comparison of the results in Tables 2 and 6 reveals that the average hit rate increases from 99.35% to 99.73% and the skip rate drops by approximately 4.02%.

Table 7 shows the RD performance after adding this rule. Compared with the results in Table 3, the *PSNR* degraded from 0.005 dB to 0.002 dB on an average, and the bit rate decreased from 0.154% to 0.015%, which indicates a significant improvement.

## 3.2 Proposed Algorithm

In summary, we proposed the intra skip decision algorithm shown in Figure 4; the skip rule is defined as follows:

(1) $R_n^{x,y} \leq R_{n-1}^{x,y}$

(2) $\{MODE_{n-1}^{x,y}, MODE_n^{x,y-1}, MODE_n^{x-1,y}\} \notin$ intra mode.

where $x$ and $y$ indicate coordinates of the MB, $n$ and $n-1$ indicate current frame and previous frame, respectively. $R_n^{x,y}$ denotes the rate value of the MB under processing in current frame after inter mode search accomplished, and $R_{n-1}^{x,y}$ denotes the rate value of the corresponding MB in the previous frame. $MODE_{n-1}^{x,y}$ denotes the best mode of the corresponding MB in the previous frame, $MODE_n^{x,y-1}$ denotes the best mode of the upper MB in the current frame, and $MODE_n^{x-1,y}$ denotes the best mode of the left MB in the current frame.

Figure 4 shows that only two parts of the process (indicated by green blocks) need to be built into the JM reference software. After completion of the inter mode search procedure, the optimal rate value of the inter mode ($R_n^{x,y}$) could be obtained. Then, compare this value to the rate value of the corresponding MB in the previous frame ($R_{n-1}^{x,y}$), if the optimal rate value of the inter mode is smaller or equal (rule 1), also, the best mode of the corresponding MB in the previous frame ($MODE_{n-1}^{x,y}$), the best mode of the upper MB in the current frame ($MODE_n^{x,y-1}$) and the best mode of the left MB in the current frame ($MODE_n^{x-1,y}$) are not intra mode (rule 2), the intra mode search will be skipped. In this situation, the best mode of the current MB is inter mode and its' optimal rate value are stored for the rest MBs and next frame. Otherwise, if

**Table 4.** Probability of the corresponding MB of the proceeding frame is the resulting optimal intra mode

| Test sequence | $QP = 20$ | $QP = 24$ | $QP = 28$ | $QP = 32$ |
|---|---|---|---|---|
| Carphone (QCIF) | 10.57% | 11.30% | 13.47% | 8.23% |
| Silent (QCIF) | 16.67% | 15.87% | 20.29% | 17.77% |
| Table Tennis (CIF) | 18.75% | 17.88% | 18.49% | 15.55% |
| Foreman (CIF) | 24.02% | 20.51% | 17.63% | 15.78% |
| Parkrun (720p) | 6.12% | 5.41% | 3.49% | 1.97% |
| Shields (720p) | 56.41% | 11.62% | 3.37% | 3.09% |

**Table 5.** Probability of the upper or left MB of the current frame is the resulting optimal intra mode

| Test sequence | $QP = 20$ | $QP = 24$ | $QP = 28$ | $QP = 32$ |
|---|---|---|---|---|
| Carphone (QCIF) | 12.45% | 11.02% | 11.95% | 11.11% |
| Silent (QCIF) | 23.78% | 22.64% | 22.75% | 22.29% |
| Table Tennis (CIF) | 40.69% | 38.39% | 39.67% | 34.11% |
| Foreman (CIF) | 30.10% | 27.74% | 23.16% | 20.96% |
| Parkrun (720p) | 63.97% | 68.19% | 73.70% | 74.00% |
| Shields (720p) | 44.01% | 32.64% | 44.45% | 37.29% |

**Table 6.** Probability of the hit rate and skip rate when applying an additional rule

| Test sequence | HR (%) | Skip (%) |
|---|---|---|
| Carphone (QCIF) | 99.69 | 52.76 |
| Silent (QCIF) | 99.93 | 62.86 |
| Table Tennis (CIF) | 99.61 | 49.63 |
| Foreman (CIF) | 99.68 | 50.93 |
| Parkrun (720p) | 99.94 | 49.96 |
| Shields (720p) | 99.52 | 48.17 |
| Average | 99.73 | 52.39 |

**Table 7.** RD performance adding an additional rule

| Test sequence | $\Delta PSNR$ | $\Delta BR$ (%) |
|---|---|---|
| Carphone (QCIF) | -0.009 | -0.130 |
| Silent (QCIF) | 0.006 | 0.086 |
| Table Tennis (CIF) | -0.007 | 0.089 |
| Foreman (CIF) | 0.003 | 0.032 |
| Parkrun (720p) | 0.002 | 0.043 |
| Shields (720p) | -0.004 | -0.029 |
| Average | -0.002 | 0.015 |

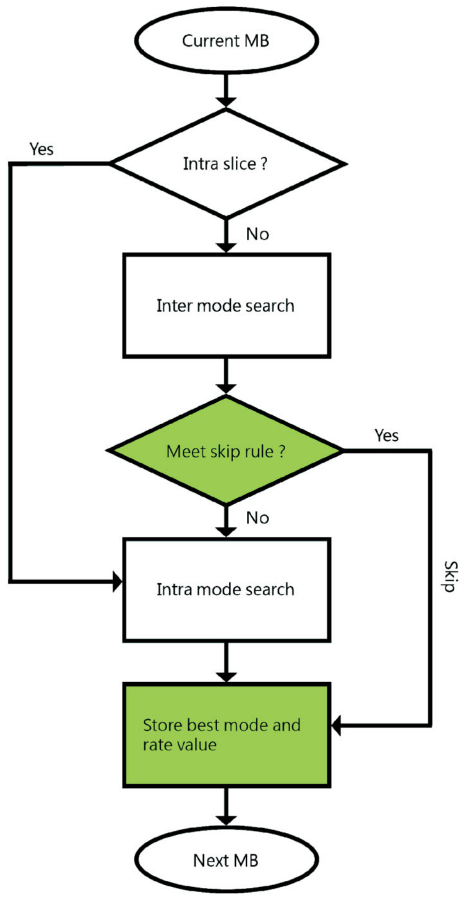


**Figure 4.** Flowchart of the proposed algorithm.

not meet the rules, the intra mode search procedure should be carried on, and finally the best mode could be either inter mode or intra mode.

## 4. Experimental Results

To verify the coding performance of our proposed intra skip decision algorithm, we performed several simulations on various test sequences after we built the proposed intra skip decision algorithm into the JM13.2 reference software.

In the first experiment, we adopted the same parameter setting as Lee and Shih used in their study [13]. All test sequences were performed with 300 frames, the RD optimization enabled, $QP$ = {20, 24, 28, 32}, search range = 16 and reference frames = 1. Table 8 shows the results of the simulation that applied five QCIF-size format test sequences. In Table 8, the measurable factors, $\Delta PSNR$ and $\Delta BR$, are used as previously defined, and the time saving factor $\Delta TS$ is defined as follows:

$$\Delta TS = \frac{T_{\text{ref}} - T_{\text{pro}}}{T_{\text{ref}}} \times 100(\%) \tag{6}$$

where $T_{\text{pro}}$ denotes time consumed by the proposed algorithm, and $T_{\text{ref}}$ denotes the time consumed by the re-

**Table 8.** Results of the simulation with 300 frames for each test sequence

| Test sequence | $QP$ | $\Delta PSNR$ | $\Delta BR$ (%) | HR (%) | Skip (%) | $\Delta TS$ (%) |
|---|---|---|---|---|---|---|
| Foreman (QCIF) | 20 | -0.002 | 0.140 | 99.77 | 42.08 | 48.90 |
| | 24 | 0.000 | 0.029 | 99.82 | 43.22 | 49.88 |
| | 28 | -0.001 | -0.028 | 99.78 | 44.91 | 50.30 |
| | 32 | -0.010 | 0.293 | 99.80 | 47.60 | 52.09 |
| Silent (QCIF) | 20 | 0.015 | 0.056 | 99.93 | 56.90 | 59.49 |
| | 24 | 0.010 | 0.071 | 99.92 | 56.80 | 61.88 |
| | 28 | -0.006 | 0.144 | 99.93 | 59.00 | 63.45 |
| | 32 | -0.017 | 0.584 | 99.91 | 61.97 | 66.11 |
| Mother and daughter (QCIF) | 20 | -0.004 | 0.053 | 99.95 | 55.04 | 58.45 |
| | 24 | 0.004 | 0.178 | 99.98 | 58.41 | 60.91 |
| | 28 | -0.008 | 0.457 | 99.96 | 62.66 | 63.51 |
| | 32 | 0.002 | -0.356 | 99.98 | 64.48 | 67.97 |
| News (QCIF) | 20 | -0.017 | 0.010 | 99.99 | 58.81 | 60.35 |
| | 24 | -0.007 | -0.047 | 99.98 | 61.09 | 63.75 |
| | 28 | -0.011 | 0.118 | 99.95 | 62.70 | 66.71 |
| | 32 | 0.022 | -0.045 | 99.95 | 67.39 | 69.52 |
| Stefan (QCIF) | 20 | -0.004 | 0.250 | 99.60 | 42.50 | 45.55 |
| | 24 | -0.008 | 0.092 | 99.61 | 43.29 | 46.56 |
| | 28 | -0.004 | 0.040 | 99.66 | 44.57 | 47.10 |
| | 32 | -0.004 | -0.042 | 99.65 | 45.67 | 48.06 |
| Average | | -0.003 | 0.100 | 99.86 | 53.93 | 57.53 |

ference software. A positive value indicates decrements for the encoding time.

In the second experiment, we adopted the same parameters used by Kim [12] and Kim et al. [15], and each test sequence consisted of 100 frames. There are two QCIF video sequences, seven CIF video sequences, and one SIF (352 × 240) video sequence. Table 9 shows the results of the simulation of the ten test sequences.

As shown in Tables 8 and 9, the average *PSNR* degradations are 0.003 and 0.002 dB, which are negligible. The average bit rate increments are 0.1% and 0.023% in Tables 8 and 9, which are minimal. In addition, the time

**Table 9.** Results of the simulation with 100 frames for each test sequence

| Test sequence | *QP* | Δ*PSNR* | Δ*BR* (%) | HR (%) | Skip (%) | Δ*TS* (%) |
|---|---|---|---|---|---|---|
| Carphone (QCIF) | 20 | -0.006 | 0.081 | 99.73 | 43.15 | 49.68 |
| | 24 | -0.017 | -0.495 | 99.74 | 44.78 | 51.86 |
| | 28 | -0.018 | -0.292 | 99.73 | 47.12 | 51.56 |
| | 32 | -0.010 | 0.479 | 99.70 | 49.97 | 54.03 |
| Stefan (QCIF) | 20 | 0.001 | 0.374 | 99.83 | 43.84 | 48.14 |
| | 24 | -0.022 | -0.006 | 99.78 | 44.49 | 49.36 |
| | 28 | 0.006 | -0.079 | 99.87 | 46.55 | 49.75 |
| | 32 | 0.007 | -0.218 | 99.90 | 47.87 | 51.11 |
| Table Tennis (SIF) | 20 | -0.002 | 0.106 | 99.81 | 44.22 | 48.58 |
| | 24 | 0.001 | 0.082 | 99.74 | 44.70 | 48.73 |
| | 28 | 0.002 | 0.191 | 99.66 | 45.64 | 49.33 |
| | 32 | -0.004 | 0.069 | 99.34 | 47.44 | 51.36 |
| Mobile (CIF) | 20 | -0.001 | 0.125 | 99.93 | 41.49 | 49.62 |
| | 24 | -0.004 | 0.102 | 99.91 | 41.86 | 49.53 |
| | 28 | 0.002 | 0.100 | 99.91 | 43.08 | 49.74 |
| | 32 | -0.006 | -0.101 | 99.93 | 45.70 | 50.56 |
| Table Tennis (CIF) | 20 | -0.001 | 0.052 | 99.78 | 44.10 | 48.14 |
| | 24 | 0.014 | 0.129 | 99.71 | 43.81 | 48.04 |
| | 28 | 0.001 | 0.194 | 99.61 | 45.19 | 49.09 |
| | 32 | -0.010 | -0.370 | 99.31 | 47.18 | 51.16 |
| Bus (CIF) | 20 | -0.007 | 0.048 | 99.82 | 41.21 | 47.27 |
| | 24 | 0.006 | 0.093 | 99.85 | 42.71 | 48.10 |
| | 28 | 0.003 | 0.135 | 99.84 | 44.64 | 48.72 |
| | 32 | 0.026 | 0.044 | 99.78 | 46.32 | 50.05 |
| Paris (CIF) | 20 | -0.014 | 0.085 | 99.92 | 52.68 | 56.79 |
| | 24 | -0.012 | 0.010 | 99.89 | 57.24 | 61.64 |
| | 28 | -0.015 | -0.096 | 99.85 | 60.47 | 64.96 |
| | 32 | -0.014 | -0.320 | 99.84 | 63.89 | 68.46 |
| News (CIF) | 20 | 0.005 | 0.230 | 99.94 | 62.91 | 64.94 |
| | 24 | -0.001 | -0.038 | 99.96 | 66.08 | 67.68 |
| | 28 | -0.006 | -0.211 | 99.94 | 68.74 | 70.77 |
| | 32 | 0.008 | 0.300 | 99.91 | 71.80 | 73.49 |
| Coastguard (CIF) | 20 | 0.000 | 0.058 | 99.92 | 43.82 | 48.31 |
| | 24 | 0.002 | -0.066 | 99.92 | 44.61 | 48.86 |
| | 28 | 0.001 | 0.141 | 99.91 | 45.83 | 50.10 |
| | 32 | 0.003 | -0.024 | 99.83 | 46.92 | 49.99 |
| Foreman (CIF) | 20 | 0.008 | 0.168 | 99.77 | 41.82 | 48.06 |
| | 24 | -0.002 | -0.150 | 99.74 | 43.29 | 48.85 |
| | 28 | 0.002 | -0.008 | 99.62 | 46.60 | 50.34 |
| | 32 | -0.008 | 0.000 | 99.60 | 49.44 | 53.41 |
| Average | | -0.002 | 0.023 | 99.79 | 48.58 | 53.00 |

saving is very close to the skip rate because of the absence of time-consuming computations in our algorithm.

We compared our algorithm with three other intra skip algorithms. Table 10 compares the coding performance of our algorithm with that of the Fuzz_HR algorithm proposed by Lee and Shih [13]. The values in this table are the average performance values when *QP* = {24, 28, 32}. The results show that the performance of our algorithm is slightly better than that of Fuzz_HR in terms of the *PSNR* and the bit rate, and our algorithm significantly improved the average time saving from 27.54% to 58.52%.

Table 11 compares the coding performance of our algorithm with that of Kim's algorithm [12]. The values in Table 11 are the average performance when *QP* = {24, 28, 32}. This table shows that the difference between the *PSNRs* of both algorithms is negligible, the bit rate performance of both algorithms is even better than that of an exhaustive search, and our algorithm significantly improved the average time saving by approximately 22.91%.

In Table 12, the performance of our algorithm and that of the algorithm proposed by Kim et al. [15] is compared. The values in this table are the average performance values when *QP* = {20, 24, 28, 32}. This table shows that the difference between the *PSNRs* of both algorithms is negligible, whereas our algorithm achieves slightly worse in bit rate performance than the algorithm of Kim et al., however, our algorithm significantly improved the time saving by approximately 17.27%.

We also applied our algorithm to high-definition test sequences. The results in Table 13 show that our algorithm has the ability to achieve a resolution of 1280 × 720 encoded with 200 frames in both Parkrun and Shields test sequences. The *PSNR* degradation is only 0.003 dB and the bit rate is even lower than that of an exhaustive search. This proves that our algorithm is suitable for video sequences of various resolutions.

**Table 10.** Performance comparison of the proposed and Fuzz_HR algorithms

| Test sequence | Algorithm | Δ*PSNR* | Δ*BR* (%) | Δ*TS* (%) |
|---|---|---|---|---|
| Foreman (QCIF) | Fuzz_HR | -0.007 | 0.260 | 24.95 |
| | Proposed | -0.004 | 0.098 | 50.76 |
| Silent (QCIF) | Fuzz_HR | 0.013 | 0.167 | 30.78 |
| | Proposed | -0.004 | 0.266 | 63.81 |
| Mother & daughter (QCIF) | Fuzz_HR | -0.010 | -0.383 | 27.56 |
| | Proposed | -0.001 | 0.093 | 64.13 |
| News (QCIF) | Fuzz_HR | -0.010 | 0.297 | 28.58 |
| | Proposed | 0.001 | 0.009 | 66.66 |
| Stefan (QCIF) | Fuzz_HR | -0.007 | 0.450 | 25.84 |
| | Proposed | -0.005 | 0.030 | 47.24 |
| Average | Fuzz_HR | -0.004 | 0.158 | 27.54 |
| | Proposed | -0.003 | 0.099 | 58.52 |

**Table 11.** Performance comparison of proposed algorithm and algorithm of Kim BG

| Test sequence | Algorithm | Δ*PSNR* | Δ*BR* (%) | Δ*TS* (%) |
|---|---|---|---|---|
| Stefan (QCIF) | Kim BG | 0.000 | -0.032 | 26.97 |
| | Proposed | -0.003 | -0.101 | 50.07 |
| Carphone (QCIF) | Kim BG | -0.001 | 0.054 | 26.13 |
| | Proposed | -0.015 | -0.103 | 52.48 |
| Mobile (CIF) | Kim BG | 0.000 | -0.019 | 39.07 |
| | Proposed | -0.003 | 0.033 | 49.94 |
| Table Tennis (CIF) | Kim BG | -0.019 | -0.226 | 28.81 |
| | Proposed | 0.002 | -0.016 | 49.43 |
| Bus (CIF) | Kim BG | -0.003 | 0.046 | 30.58 |
| | Proposed | 0.012 | 0.091 | 48.95 |
| Paris (CIF) | Kim BG | -0.001 | -0.041 | 26.87 |
| | Proposed | -0.014 | -0.135 | 65.02 |
| Average | Kim BG | -0.004 | -0.036 | 29.74 |
| | Proposed | -0.004 | -0.038 | 52.65 |

**Table 12.** Performance comparison of proposed algorithm and algorithm of Kim et al.

| Test sequence | Algorithm | Δ*PSNR* | Δ*BR* (%) | Δ*TS* (%) |
|---|---|---|---|---|
| Table Tennis (SIF) | Kim et al. | -0.011 | 0.288 | 38.90 |
| | Proposed | -0.001 | 0.112 | 49.50 |
| News (CIF) | Kim et al. | 0.003 | -0.080 | 40.20 |
| | Proposed | 0.002 | 0.070 | 69.22 |
| Coastguard (CIF) | Kim et al. | 0.001 | -0.010 | 37.50 |
| | Proposed | 0.002 | 0.027 | 49.32 |
| Foreman (CIF) | Kim et al. | 0.001 | -0.040 | 32.50 |
| | Proposed | 0.000 | 0.003 | 50.16 |
| Average | Kim et al. | -0.002 | 0.040 | 37.28 |
| | Proposed | 0.001 | 0.053 | 54.55 |

**Table 13.** Results of simulations with 200 frames for each test sequence

| Test sequence | *QP* | Δ*PSNR* | Δ*BR* (%) | HR (%) | Skip (%) | Δ*TS* (%) |
|---|---|---|---|---|---|---|
| Parkrun (720p) | 20 | 0.001 | 0.011 | 99.92 | 45.48 | 50.52 |
| | 24 | 0.000 | 0.024 | 99.93 | 45.34 | 50.51 |
| | 28 | 0.000 | 0.023 | 99.96 | 48.13 | 50.72 |
| | 32 | 0.003 | 0.029 | 99.96 | 51.07 | 52.23 |
| Shields (720p) | 20 | 0.000 | 0.015 | 99.24 | 31.84 | 36.54 |
| | 24 | -0.003 | 0.027 | 99.48 | 43.20 | 48.09 |
| | 26 | -0.006 | -0.064 | 99.73 | 51.51 | 53.96 |
| | 32 | -0.015 | -0.249 | 99.51 | 55.26 | 57.50 |
| Average | | -0.003 | -0.023 | 99.49 | 45.45 | 50.02 |

## 5. Conclusions

In this study, we presented a simple, highly efficient intra skip decision algorithm that utilizes pre-calculated information. In our algorithm, we developed a skip rule that is based on the best mode and the rate value of the RD cost function, all of which are pre-calculated in the corresponding MB of the previous frame and the neighbouring MBs of the current frame. Because the algorithm does not require additional time-consuming computations, the time saving for the intra prediction mode is very close to the skip rate. Our experimental results demonstrated that the proposed algorithm can significantly reduce encoding time by approximately 50% compared with the time needed during an exhaustive search. With our algorithm, the time saving is increased by 17%–30% compared with three other existing algorithms, whereas the differences in *PSNR* degradation is negligible and the bit rate increment is minimal.

The future work of this research will extend our algorithm to the new video coding standard known as HEVC (high efficiency video coding). Since HEVC and H.264 have similar operational flow, and our algorithm is simple and easy to be implemented in this new standard.

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