Journal of Theoretical and Applied Information Technology
15 August 2012. Vol. 42 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

# AN IMPROVEMENT METHOD OF SUBJECTIVE PICTURE QUALITY WITHIN CONCERNED REGIONS FOR H.264 VIDEO CODING

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**ABSTRACT**

Video compression is very crucial method which is used to reduce the quantity of data used to represent digital video pictures. However, most video compression is loss when the video pictures data is quantized. So a quantizer is key factors for adjusting the bitrate and controlling the picture quality. Importantly, if the concerned region of video sequence takes on high level picture quality, the subjective picture quality could be improved. First, on the basis of the subjectively concerned region which can be determined using motion vectors within a video sequence, a classification method is suggested. Furthermore, we propose a method that allocation a relatively small quantization step-size for the concerned region compared with the other regions within a video sequence and thus improves picture quality. The measurement of the objective *PSNR* and the subjective image quality of result presented that subjective picture quality can be improved by proposed method.

**Keywords:** *Quantization Step-Size, Subjective Picture Quality, Concerned Region, DSCQS*

## 1. INTRODUCTION

The supply of various multimedia services, such as pictures and videos, has been developed according to the recent development in digital signal processing, storage media and device, and transmission technologies including the wide distribution of computers and Internet. In particular, the application of video services has been significantly increased due to the coding technology for huge video data. The video coding standard for supplying various compression bitrates according to various communication networks and its terminals are established as MPEG-1, 2, 4, H.261, H.262, H.263, and H.264 [1].

The video coding can be carried out through a coding process in which it is essential to use a quantization algorithm. The quantization algorithm is classified into scalar and vector quantizers [2-5]. In an MPEG-2 coding method [6] or establishing a class of digital TV quality uses a scalar quantizer that has a quantization step-size from 1 to 32. In the case of the coding process established in the present time [1, 4, 5], such as H.264 and MPEG-4 Part 10, it uses a total of 52 quantization step-sizes.

Most of conventional studies on such a scalar quantizer [7, 8] are conducted to draw the relationship between the bitrate and the quantization step-size, and the quantization step-size and the coding performance through considering the quantizer. The scalar quantizer causes certain losses due to the quantization of decimal points where the relationship between the loss in picture quality and the reduction in bitrates represents an inverse proportion. The quantization step-size can be determined at a range where the resolution and picture quality can be neglected. The resolutions apply to various multimedia devices use in the present time show lots of differences compared to that of the conventional monitors. Thus, the quantization step-size is to be selected as an adaptable manner.

There are several conventional approaches for concerned regions based rate control. The method in [9] does not include a robust method to detect the concerned regions. And the background is always encoded with the coarsest quantization level according to Maximum Bit Transfer (*MBT*). The method in [10] can just accurately detect the concerned regions of skin color at the facial type video and adjusts the distortion weight parameter and variance to control the picture qualities at different regions based on H.263+. The method in [11] uses difference of the Cr and RGB to detection the "face" which is regarded as concern regions. So the parts of skin color can be detected. It uses fuzzy logic control method to control and give adaptively weighted factor to each macroblock (*MB*), which is based on TMN8 of H.263+ and different bits are

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

allocated to each *MB* according to the variance variation in rate and distortion model. The method in [12] can detect and track the human face in complicated and moving background. And quantization parameters are flexibility allocated to different *MB*s based on TMN8 of H.263. The method in [13] presents a region-based video codec and it is compatible with the H.263+ standard, and its associated rate control algorithm for low variable-bit-rate (*VBR*) video.

This study proposes a method that brings an improvement in subjective picture quality by applying a quantization step-size differentially according to the concerned region within a video sequence. Then, this study introduces a method that identifies subjectively concerned regions according to the characteristics of videos. Various types of videos, which are used in recent, have their own motion vectors and that can be classified as the video that represents a whole scale of motion like backgrounds, that shows a lot of motion at the central of an object, which has some movements, and that represents a lot of motion at the contour of a screen like a zoom-out screen. This study proposes a method that automatically applies the quantization step-size differentially according to the concerned region after classifying subjectively concerned regions. That is, the quantization step-size in the concerned region within a video sequence can be determined as a small scale relatively compared to that of the region out of the concerned region.

This study consists of five chapters. Chapter 2 shows the quantizer of the H.264 in a coding process. Chapter 3 investigates the improvement of picture quality in the subjectively concerned region proposed in this study. Chapter 4 represents the results of the analysis of experiments. Finally, Chapter 5 shows the conclusion of this study.

## 2. H.264 SCALAR QUANTIZER

The quantization regards in a general aspect means that it replaces input values determined in a certain region to much smaller approximate values. The scalar quantizer is used to apply a video coding process like the H.264 divides the real value input from a discrete cosine transform into a quantization step-size and then it rounds up to the nearest integer in which it is difficult to verify the original exact real value of the rounded integer and causes certain losses. In general, a quantizer can be determined as follows [4].

$$FQ = \left\lceil \frac{X}{Qstep} \right\rceil \qquad (1)$$

$$Y = FQ \cdot Qstep \qquad (2)$$

Where $X$ is an input coefficient, $Qstep$ is the quantization step-size, $FQ$ is the signal value quantized through a forward direction quantizer, and $Y$ is the restored signal value decoded through a reverse quantization.

The quantization of the H.264 is supported by the standard determined in the total of 52 quantization step-sizes. Also, the quantization step-size can be used by indexing it according to quantization parameters. The quantization parameters can be doubled according to the increase in the value by six and then the quantizer is able to flexibly and precisely control the balance between the bitrate and the picture quality due to the wide range of the quantization step-size. Table 1 shows the quantization parameters and indexed step-sizes.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Qp* | 0 | … | 6 | … | 12 | … | 24 |
| *Qstep* | 0.625 | | 1.250 | … | 2.500 | … | 10.00 |
| *Qp* | 30 | … | 36 | … | 42 | … | 51 |
| *Qstep* | 20.00 | … | 40.00 | … | 80.00 | … | 224.0 |

Table 1: Quantization Parameters and Step-sizes of The H.264

## 3. PICTURE QUALITY IMPROVEMENT METHOD IN SUBJECTIVELY CONCERNED REGIONS

Although the application of the quantization step-size, which is determined by considering a generated bitrate, by rule may present an improvement in bitrates and compression, it is not a desirable way to improve differential picture quality according to the importance of pictures within a video. Thus, this study proposes a method that applies a quantization step-size differentially through considering concerned regions within a video. For performing this method, this study introduces a reference for subjectively concerned regions within a video and applies the quantization

Journal of Theoretical and Applied Information Technology
15 August 2012. Vol. 42 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

step-size differentially according to these concerned regions.

3-1 Criterion of a subjectively concerned region

A subjectively concerned region can be determined using motion vectors.

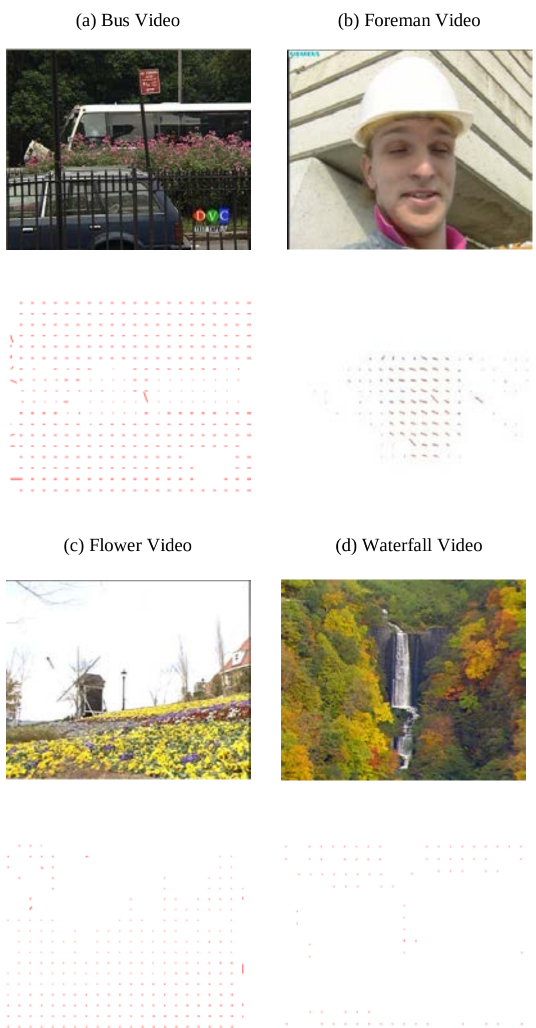


*Figure 1: Motion vectors for each video*

Figure 1 shows the motion vectors according to the characteristics of videos. The Bus video is made by moving a camera from right to left where motion vectors are presented at the central of the video. Therefore, it is considered that the concerning is focused on the central region. The Foreman video demonstrates the movement of the object located at the central of the video under the fixing of the background in which motion vector values are presented at the central of the video only. It shows that the concerning is focused on the central region that represents certain movements rather than that of the whole region of the video. The Flower video shows the movement of the object located at the lower of the video. So it shows that the concerning is focused on the lower region that represents certain movements rather than that of the whole region of the video. And the waterfall video is gradually expanded at the contour of the video. So it shows that the concerning is focused on the contour region that represents certain movements rather than that of the whole region of the video. Based on these characteristics, the present screen can be classified by following five different cases in the aspect of subjective importance

Central focus video: It shows motion vector values at the central region of a video in which the motion vector values at the contour regions are determined by '0'.

Contour focus video: It shows motion vector values at the contour of a video like a zoom-out in a video in which the motion vector along the vertical direction represent large values.

Lower focus video: It shows motion vector values at the lower region of a video only in which the motion vector values at the upper region are presented by '0'.

Upper focus video: It shows motion vector values at the upper region of a video only in which the motion vector values at the lower region are presented by '0'.

Whole focus video: In the case of the movement of the entire video like the video moved along the vertical or horizontal direction, it shows no concerning on a specific region but focuses the entire video.

3-2 Differential application of a quantization step-size

In a coding process in a video according to the importance of videos, the differential application of the quantization step-size brings an improvement in picture quality. The quantization step-size can be applied as a differential manner according to the subjectively concerned region. Figure 2 illustrates the differential application of the quantization step-size for the slice along the vertical direction in a video.

As illustrated in Figure 2, the specific value of the quantization step-size for applying it differentially according to the slice within a video can be described by following equations. First, it is necessary to find the average of the quantization

Journal of Theoretical and Applied Information Technology
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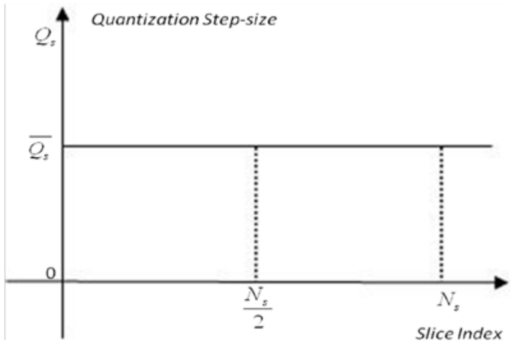
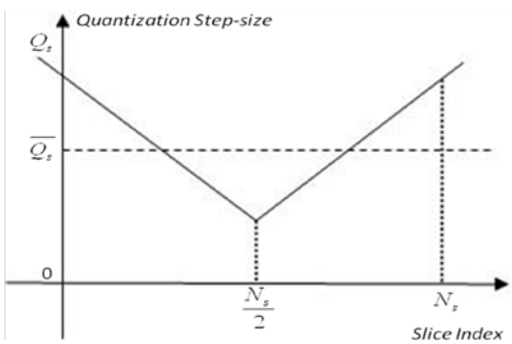
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

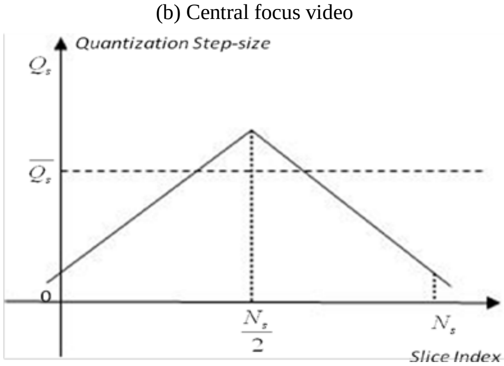
step-size, which is $\overline{Q_s}$, for the entire slice within a video.



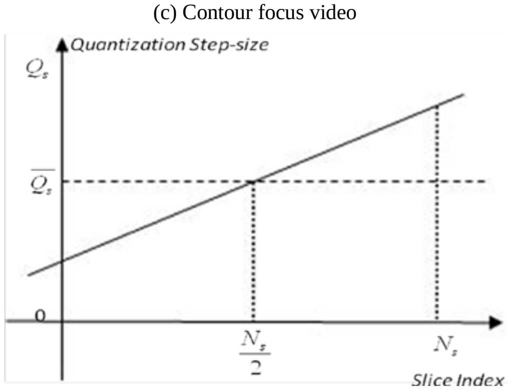

(a)Application of the uniformed quantization step-size for each slice



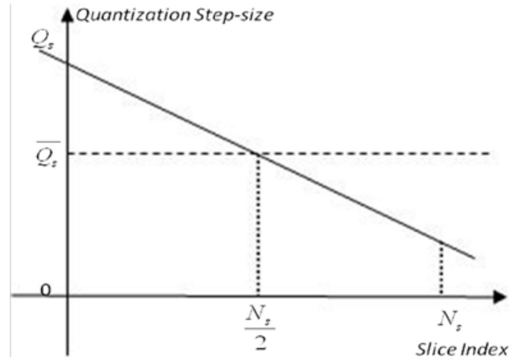

(b) Central focus video




(c) Contour focus video




(d) Upper focus video




(e) Lower focus video

*Figure 2: Differential application of the quantization step-size for each concerned video type*

$$\overline{Q_s} = \frac{\sum_{i_s}^{N_s} Q_s(i_s)}{Ns} \qquad (3)$$

Where $i_s$ is the slicing order, and $N_s$ is the number of total slices in the video.

The new value of the quantization step-size, $\hat{Q}_s$ for each slice according to the concerned region of a video can be determined as follows:

Lower and upper focus videos

$$\hat{Q}_s(i_s) = \alpha(i_s - \frac{N_s - 1}{2}) + \overline{Q_s}, 0 \le i_s < N_s \qquad (4)$$

Where $\alpha$ is a constant that shows different values according to each type of video. The values are determined as $\alpha \le 0$ and $\alpha \ge 0$ for the lower and upper focus videos respectively.

Central and contour focus videos

In the case of the total number of slices in a video, $N_s$ that is determined as an even number, the equation can be configured as follows.

$$\hat{Q}_s(i_s) = \alpha_1(i_s - \frac{\frac{N_s}{2} - 1}{2}) + \overline{Q_s}, 0 \le i_s < \frac{N_s}{2}$$

$$\hat{Q}_s(i_s) = \alpha_2(i_s - \frac{\frac{N_s}{2} - 1}{2} - \frac{N_s}{2}) + \overline{Q_s}, \qquad (5)$$

$$\frac{N_s}{2} \le i_s < N_s$$

Where $\alpha_1$ and $\alpha_2$ are constants. The values are determined as $\alpha_1 \le 0$ , $\alpha_2 \ge 0$ and $\alpha_1 = |\alpha_2|$ for the

Journal of Theoretical and Applied Information Technology
15 August 2012. Vol. 42 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

central focus video and $\alpha_1 \geq 0$, $\alpha_2 \leq 0$ and $\alpha_1 = |\alpha_2|$ for the contour focus video.

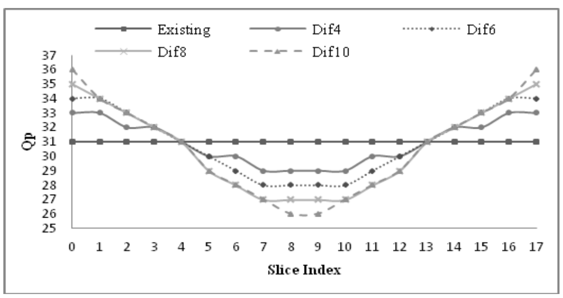
If $N_s$ is determined as an odd number, the equation can be determined as follows:

$$\hat{Q}_s(i_s) = \alpha_1 \left(i_s - \frac{\left\lceil \frac{N_s}{2} \right\rceil - 1}{2}\right) + \overline{Q_s}, 0 \leq i_s < \frac{N_s}{2}$$

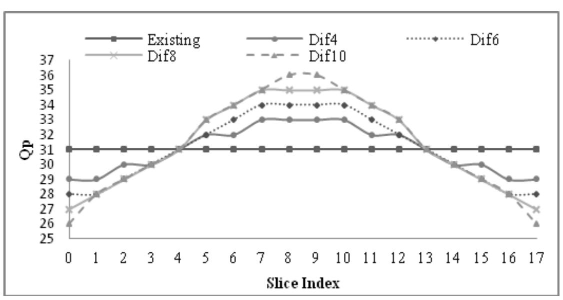
$$\hat{Q}_s(i_s) = \alpha_2 \left(i_s - \frac{\left\lfloor \frac{N_s}{2} \right\rfloor - 1}{2} - \left\lceil \frac{N_s}{2} \right\rceil\right) + \overline{Q_s}, \quad (6)$$

$$\frac{N_s}{2} \leq i_s < N_s$$

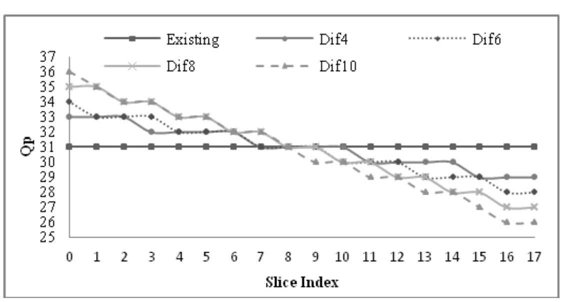
Where $\lceil\ \rceil$ is a rounding up calculation, $\lfloor\ \rfloor$ is a descending calculation, and $\alpha_1$, $\alpha_2$ are determined as $\alpha_1 \leq 0$, $\alpha_2 \geq 0$ for the central focus video and $\alpha_1 \geq 0$, $\alpha_2 \leq 0$ for the contour focus video.



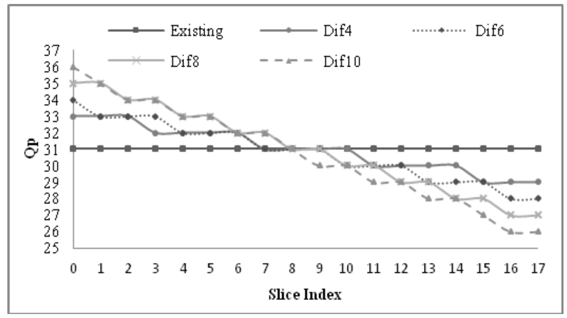

(a) Assigning of the quantization step-size in a central focus method




(b) Assigning of the quantization step-size in a contour focus method




(c) Assigning of the quantization step-size in a lower focus method




(d)Assigning of the quantization step-size in a upper focus method

*Figure 3: Assigning of the quantization step-size (Dif n = Difference between the maximum and minimum values of the quantization step-size is to be determined by n)*

Figure 3 shows the case that configures the quantization step-size based on Eq. (5) for the central and contour focus videos in the case of the value of $N_s$ that is determined by 18. Here, the new quantization step-size can be determined by various real values. However, as shown in Table 1, in the case of the H.264, because 52 quantization step-sizes are only defined, the actual quantization step-size can be determined by the nearest value through comparing the quantization step-size calculated by using Eq. (5) and 52 defined values. It means that the value can be determined by the quantization step-size that has the least difference in absolute values by calculating the difference of absolute values between the calculated value of the quantization step-size and the defined value.

As shown in Figure 3, in the assigning method of the quantization step-parameter (quantization step-size) with the central focus way, small and large values of the quantization step-size are assigned to the slice at the central and contour regions respectively. However, in the contour focus method, small and large values of the quantization step-size are assigned to the contour and central regions respectively. In the application of Eq. (5), the difference in the value of the quantization step-size between adjacent slices should not be determined by more than double. If the difference in the value shows more than double, it may cause the deterioration of picture quality due to the block effect at the border of slices.

## 4. EXPERIMENTS AND RESULTS

The JM10.2 [15] that is a standard coding software tool of the H.264 is used to the experiment

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15 August 2012. Vol. 42 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

for the method proposed in this study where Bus, Flower, Foreman, and Waterfall videos with horizontal and vertical resolutions of 352 and 228 pixels, respectively, were selected. Figure 4 shows the characteristics of these four videos.

(a) Bus Video

Overall dark. The camera moves from right to left. This is the most complex video in these video samples.

(b) Flower Video

Overall bright. Similar colors are mixed as brunch. colors are changed in the picture. It is also complex, and the camera moves from left to right.

(c) Foreman Video

Overall bright, central movement, and no background movement. It is a simple video and shows no changes in the background.

(d) Waterfall Video

Overall no movement, Picture is gradually expanded at the central of the video. Similar color brunch is mixed.

*Figure 4: Video characteristics*

The B-screen is not included due to the use of the H.264 baseline profile, and 15 screens are configured as one GOP in which each video applies 60 screens. The number of slices are the same as for each screen and that are determined by 18 along the vertical direction.

The quantization step-size was differentially applied for the 18 slices for each screen using the value of $\alpha$ determined in Eq. (5). Also, the coding is performed as an objective bitrate for the original video based on three different cases, such as 4, 6, and 8, from the classification of the difference between the maximum and the minimum values of the quantization step-size.

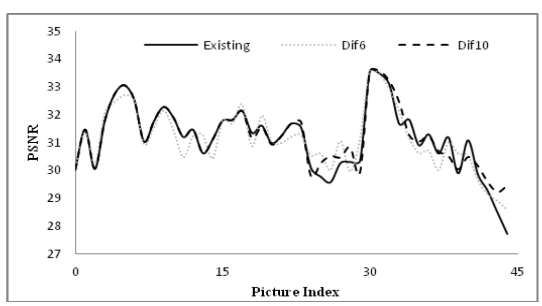
4-1 Criterion of a subjectively concerned region

This study investigated the *PSNR* (peak signal to noise ratio) that is an objective picture quality criterion. The existing method applied a bitstream coded with of 1.0Mbps. Then, as illustrated in Figure 5, 6, 7 and 8 the quantization step-size is differentially assigned with the unit of slices using the lower focus method for Flower video, using the central method for Bus and Foreman videos, and using the contour focus for Waterfall video respectively, according to the criterion of subjectively concerned regions.

Table 2 shows the average value of the *PSNR* and the total number of bits for 60 screens in the Flower video and maximum difference of quantization parameters within picture is set to 4, 6, 8 and 10. Figure 5 represents the *PSNR* values for 45 screens as the first GOP is not included. It can be seen that the values of the *PSNR* are decreased according to the differential application of the quantization step-size between slices compared to the method that applies the same quantization step-size values for all slices. In the case of the Dif6 (the difference in the quantization step-size between the maximum and the minimum values was determined by 10), the *PSNR* is decreased about 0.03dB, and it is decreased about 0.04dB for the Dif10. In part (b) of Figure 5, maximum difference of quantization parameters within picture is set to 6 and 10 within the second GOP.

*Table 2: Average PSNR and the total number of bits, while coding was performed as 1.0MBps bitrate for the Flower video based on the lower focus method*

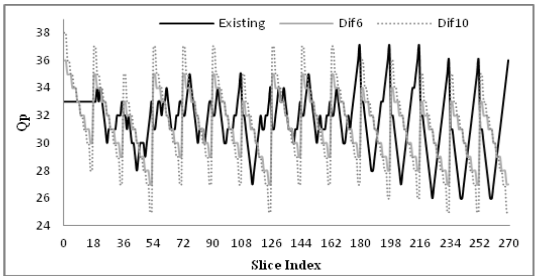
| Video | PSNR /Bits | Existing method | Dif4 | Dif6 | Dif8 | Dif10 |
|---|---|---|---|---|---|---|
| Flower | PSNR | 31.05 | 31.09 | 31.02 | 31.01 | 31.10 |
| | Bits | 2023 024 | 2009 912 | 2013 304 | 2011 616 | 2029 032 |




(a) *PSNR*

Journal of Theoretical and Applied Information Technology
15 August 2012. Vol. 42 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195



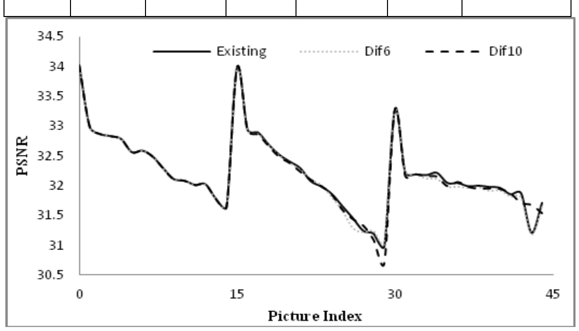

(b) Maximum difference of quantization parameters within picture is set to 6 and 10

*Figure 5: Results of the assigning of the quantization step-size for the Flower video with the lower focus method*

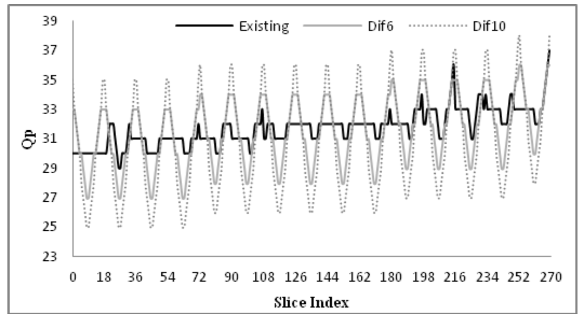
Table 3 shows the average value of the *PSNR* and the total number of bits for 60 screens in the Bus video and maximum difference of quantization parameters within picture is set to 4, 6, 8 and 10. Figure 6 represents the *PSNR* values for 45 screens as the first GOP is not included. It can be seen that the values of the *PSNR* is decreased according to the differential application of the quantization step-size between slices compared to the method that applies the same quantization step-size values for all slices. In the case of the Dif6 (the difference in the quantization step-size between the maximum and the minimum values was determined by 10), the *PSNR* is decreased about 0.02dB, and it is decreased about 0.03dB for the Dif10. In part (b) of Figure 6, maximum difference of quantization parameters within picture is set to 6 and 10 within the second GOP.

Table 3: Average *PSNR* and the total number of bits, while coding was performed as 1.0MBps bitrate for the Bus video based on the central focus method

| Video | PSNR /Bits | Existing method | Dif4 | Dif6 | Dif8 | Dif10 |
|---|---|---|---|---|---|---|
| Bus | PSNR | 32.36 | 32.36 | 32.34 | 32.33 | 32.33 |
| | Bits | 2004 184 | 2006 488 | 2004 728 | 2005 728 | 2005 936 |




(a)*PSNR*



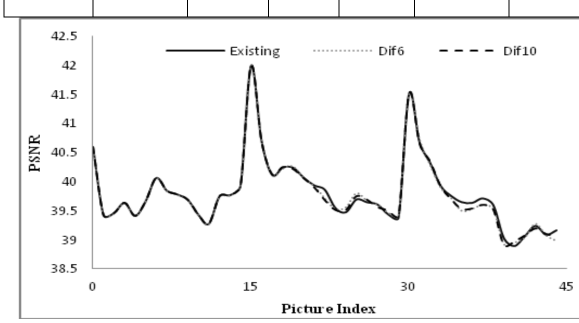

(b) Maximum difference of quantization parameters within picture is set to 6 and 10

*Figure 6: Results of the assigning of the quantization step-size for the Bus video with the central focus method*

Table 4 shows the average value of the *PSNR* and the total number of bits for 60 screens in the Foreman video and maximum difference of quantization parameters within picture is set to 4, 6, 8 and 10. Figure 7 represents the *PSNR* values for 45 screens as the first GOP is not included. It can be seen that the values of the *PSNR* is decreased according to the differential application of the quantization step-size between slices compared to the method that applies the same quantization step-size values for all slices. In the case of the Dif6 (the difference in the quantization step-size between the maximum and the minimum values was determined by 10), the *PSNR* is decreased about 0.01dB, and it is decreased about 0.02dB for the Dif10. In part (b) of Figure 7, maximum difference of quantization parameters within picture is set to 6 and 10 within the second GOP.

Table 4. Average *PSNR* and the total number of bits, while coding was performed as 1.0MBps bitrate for the Foreman video based on the central focus method

| Video | PSNR /Bits | Existing method | Dif4 | Dif6 | Dif8 | Dif10 |
|---|---|---|---|---|---|---|
| Foreman | PSNR | *39.70* | 39.70 | 39.69 | 39.69 | 39.68 |
| | Bits | 2006 992 | 2007 096 | 2007 328 | 2006 848 | 2006 432 |




(a)*PSNR*

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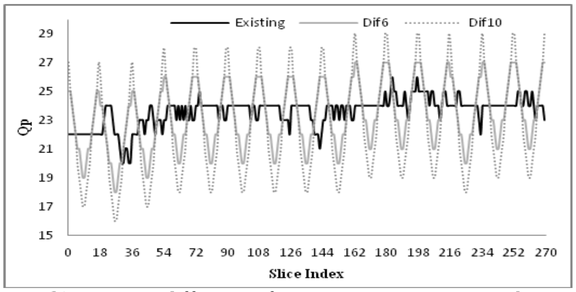


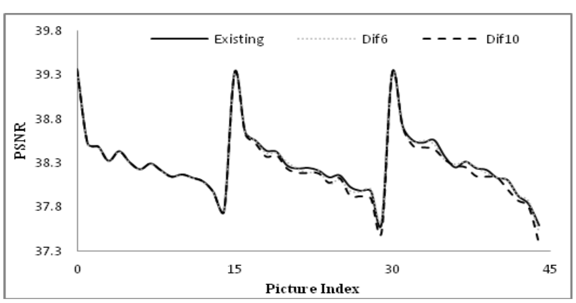

(b)Maximum difference of quantization parameters within picture is set to 6 and 10

*Figure 7: Results of the assigning of the quantization step-size for the Foreman video with the central focus method*

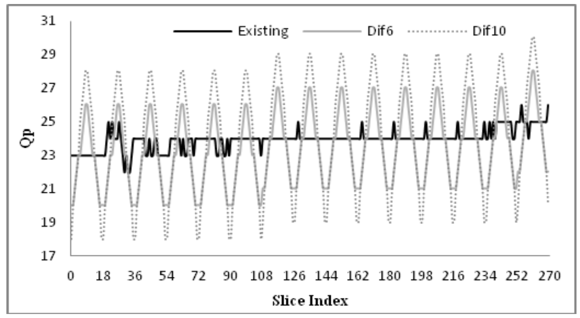
Table 5 shows the average value of the *PSNR* and the total number of bits for 60 screens in the Waterfall video and maximum difference of quantization parameters within picture is set to 4, 6, 8 and 10. Figure 8 represents the *PSNR* values for 45 screens as the first GOP is not included. It can be seen that the values of the *PSNR* is decreased according to the differential application of the quantization step-size between slices compared to the method that applies the same quantization step-size values for all slices. In the case of the Dif6 (the difference in the quantization step-size between the maximum and the minimum values was determined by 10), the *PSNR* is decreased about 0.01dB, and it is decreased about 0.02dB for the Dif10. In part (b) of Figure 8, maximum difference of quantization parameters within picture is set to 6 and 10 within the second GOP.

| Video | PSNR /Bits | Existing method | Dif4 | Dif6 | Dif8 | Dif10 |
|---|---|---|---|---|---|---|
| Bus | PSNR | 32.24 | 38.25 | 38.23 | 38.23 | 38.22 |
| | Bits | 2012 928 | 2011 672 | 2011 424 | 2011 352 | 2011 384 |

Table 5. Average *PSNR* and the total number of bits, while coding was performed as 1.0MBps bitrate for the Waterfall video based on the contour focus method




(a)*PSNR*




(b)Maximum difference of quantization parameters within picture is set to 6 and 10

*Figure 8: Results of the assigning of the quantization step-size for the Waterfall video with the contour focus method*

4-2 Measurement of subjectively concerned picture quality

In this paper, we used DSCQS (Double Stimulus Continuous Quality Scale) method to measurement of subjectively concerned picture quality [16]. According this method, the assessors can observe two videos that one is an original video and the other is a processed video by existing method or proposing method at the monitor. Assessors evaluated pictures quality of both videos using an ITU-R quality scales (Excellent=5, Good=4, Fair=3, Poor=2, Bad=1) [14].

The presentation of the test material:

Step 1 Video A (Original or Processed) 10s,

Step 2 Gray 3s,

Step 3 Video B ( Original or Processed) 10s,

Step 4 Gray 3s,

Step 5 the presentation order of original and process videos was random. The assessors are asked to evaluate the videos and sequence. And assessors are distanced from the video as much as three times of the diagonal length of the monitor used in the play of videos. Final score of subjectively picture quality of assessed video was calculated as follows

$$U = \frac{1}{N}\sum_{i=1}^{N} u_i \qquad (7)$$

Where $u_i$ is score which is determined by each assessor, $N$ is quantity of assessor.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

*Table 6. Results of the subjectively concerned picture quality for the bitrate of 0.8Mbps for interest regions*

| Video | Existing method | Proposing method | | | | |
|---|---|---|---|---|---|---|
| | | Dif4 | Dif6 | Dif8 | Dif10 | Focus |
| Bus | 2.8 | **3.6** | 2.6 | 2.0 | 1.8 | Central |
| Flower | 3.0 | **3.8** | 2.8 | 2.4 | 2.0 | Lower |
| Foreman | 2.4 | 2.6 | **3.4** | 2.2 | 1.8 | Central |
| Waterfall | 1.8 | 2.2 | **3.0** | 1.4 | 1.2 | contour |

In the results, because the Foreman and bus videos that showed no movements in the background and certain movements at the central region only represented an increase in its concerning, it represented good picture quality in the aspect of a subject manner based on the assigning of the quantization step-size with the central focus method. For the Foreman video, the desirable difference between the maximum and the minimum values of the quantization step-size between slices is 6. However, for the Bus video, the desirable difference between the maximum and the minimum values of the quantization step-size between slices is 4. If the difference between the maximum and the minimum values show more than 8, the subjectively concerned picture quality is getting worse. Because the contour focus method shows the reappearance of contour regions as the screen is zoomed out as the same as that of the Waterfall video and active movements, the contour region is more important than the central region in the aspect of subjective manner. Therefore, the assigning of small values of the quantization step-size to the slice at the contour region brings good subjective picture quality. It can be seen that the difference between the maximum and the minimum values of the quantization step-size between slices that is determined by 6 will present the most excellent picture quality. If the difference exceeds 8, the subjective picture quality significantly decreased. And The Flower video shows the movement of the object located at the lower of the video. So it shows that the concerning is focused on the lower region that represents certain movements rather than that of the whole region of the video. Here, the desirable difference between the maximum and the minimum values of the quantization step-size between slices is 4. If the difference between the maximum and the minimum values shows more than 8, the subjectively concerned picture quality was getting worse.

Although the objective *PSNR* value that is the average value of the entire screen slightly decreased for the differential configuration of the quantization step-size within the video sequence according to concerned regions as shown in Table 6, the subjective picture quality that has a focus on concerned points within the video sequence increased. It means that the measurement of objective picture quality only will not fully satisfy the visual picture quality of human being. In addition, it is possible to present an improvement effect in picture quality by applying the results of the evaluation of subjective picture quality to the objective picture quality while there is no change in bitrates.

## 5. CONCLUSION

This study analyzed the motion vectors within video in a H.264 coding system and then classified the video as different ways, such as entire focus, central focus, contour focus, lower focus, and upper focus. Then, this study applied the quantization step-size (parameter) to the concerned region differentially. In addition, this study proposed a method that improves subjective picture quality based on the visual sensation of human being by determining a proper quantization step-size with the combination of differential quantization step-sizes through reflecting the results of the evaluation of subjective picture quality to the results of the measurement of objective picture quality. Furthermore, this study obtains an improvement effect in subjective picture quality compared to the conventional method through the intensive application of the quantization step-size in a coding process before analyzing the subjectively concerned region using the proposed method. Also, this study verifies that the reasonable difference between the maximum and the minimum values of the quantization step-size within a video was about 4-6 in the case of the quantization step-size that is to be differentially applied.

Although this study focused on the H.264 video coding, it can be directly used to other types of videos including the H.264. In addition, it can be expected that this study will be extensively applied with other various bit string transformation techniques.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

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