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An Improved H.264 Encoded Algorithm Based on Weber-Fechner Law

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Abstract

With the study of human visual system (HVS), people find that the human eye shows different degree of sensitivity to different light signals. A higher background brightness region of the human eye for the distortion, the degree of sensitivity will be greatly reduced. The human eye's sensitivity will be greatly reduced to the distortion of a higher brightness background region. This finding is discribed in Weber-Fechner law. Therefore, the encoder can be improved by employing this characteristic of human visual system. In this paper, the authors use this characteristic to improve the H.264 video coding algorithm. In order to improve the compression efficiency of encoder, give the brightness of different regions with different levels of quantification by adjusting the quantization step size (QP), without affecting the subjective quality of video. Experimental results show that the output bit rate decrease up to 10% -20% by using this improved algorithm in H.264 reference encoder, and the subjective quality of decoded image by using this improved algorithm is as good as the standard H.264 encoders.

Keywords: *Human visual system (HVS); Visual redundancy; Weber-Fechner law; H.264; Variable step*

1. Introduction

With the development of video codec technology, there have been many excellent video compression standards. These standards improved video compression while maintaining video quality, which greatly facilitates the storage and transmission information of high quality video. H.264 is developed by the ITU-T VCEG (Video Coding Experts Group) and the Joint Video Team (JVT) of ISO / IEC's MPEG (Moving Picture Coding Experts Group). The main idea of the H.264 standard video codec is the same with other existing standards, which is block-based hybrid coding method. In the digital video coding standard H.264, it eliminates spatial redundancy of the video through a variety of intra prediction modes and integer DCT transform effectively; it eliminates the temporal redundancy of video sequence by interframe prediction to the quarter-pixel precision and interpolation; it eliminates redundant encoding adaptive of the video through CABAC effectively. By using these techniques, H.264 video coding standard greatly improves video compression rate while ensures the video quality.

At present, study on the Improvement of H.264 focused on optimizing complex algorithms to improve the computing speed of the encoder, and how to eliminate video

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temporal redundancy, spatial redundancy, coding redundancy more effectively. However, in most practical applications, Human visual system is the ultimate recipient of the video. Therefore, the video quality largely depends on the person's subjective feelings. A large number of experimental results show that the human visual system cannot perceive all changes of the images and videos in detail. When the changes have not reached a certain threshold, the human eye can not perceive its changes; this threshold is called JND (Just Noticeable Distortion) [3-5]. In other words, there are some mental visual redundancy in images and videos. Therefore, the elimination of visual mental redundancy has become an opportunity and challenge in the field of video and images compression.

Through the studies of human visual system, we have found that as the brightness increases, the human eye's sensitivity to different light intensity gradually decrease, the brightness higher, the JND larger. Thus, there is a large number of redundancies information in images and video’s high-brightness region which the human visual system cannot detect. According to this characteristic, we can further reduce the redundancy in images and videos.

The method which we presented in this paper detect the brightness information of the video signal, according to the brightness information of different regions to adjust the quantization step size, and give different levels of quantization for different regions. In the decoder side, through the iteration method detect the quantitative step, and then carry out the inverse quantization. The algorithm complexity is low. Experimental results show that when the subjective quality of the video in decoding side basically unchanged, encoding bit-rate declined in 10% -20%, which has increased the compression ratio.

The remainder of the paper is structured as: the Section 2 introduces the Weber-Fechner Law, and Section 3 presents the detailed realization of improved H.264 encoder using Weber-Fechner Law, and to validate the proposed algorithm, the Section 4 illustrates some experimental tests, results and analysis, and the last Section concludes the whole paper and puts forward the future direction.

2. Model of Human Visual Sensitivity

Some physiologists find human eyes can distinguish subtle changes, due to adaptive characteristics to light intensity. Light sensitive cells of the retina and the visual neurons are automatically adaptive to light intensity. Contrast threshold refers to the minimal difference of brightness contrast can be observed with eyes. Figure 1 shows the curve of the contrast threshold changing with the background brightness.

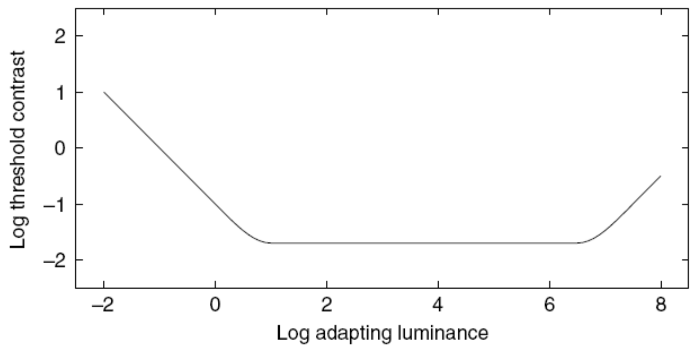


Figure 1. Curve of the Contrast threshold changing with the Background Brightness

German physiologist Weber in his study found that the difference of the same stimulus must reach a certain percentage that can be felt. This ratio is a constant, with formula:

$$\frac{\Delta s}{s} = k \tag{1}$$

Where Δs is the difference in the amount of stimulation, s is the amount of stimulate, k is a constant.

German physicist Fechner in the basis of Weber's study made an assumption in 1860, see the smallest noticeable difference (continuous threshold difference, JND) as a volume unit of the sense, for each additional one difference threshold, mental capacity will increase a unit. This can derive a formula as follows:

$$S = k \ln I + C \tag{2}$$

Where S is the amount of sense, k is a constant, I is the amount of physical stimulation, C is a integral constant. General formula can be expressed as:

$$S = k \log I \tag{3}$$

The implication is that sense of quantity is proportional to the logarithm value of physical quantity. It is means that the increase of the amount of sense is behind the increase of physical quantities, a geometric increase in physical quantities and mental capacity is growth in arithmetic progression, this empirical formula is known as Fechner's law or the Weber - Fechner law [6-9]. Human visual system to luminance perception is also in line Weber - Fechner law, it is said that the ability of the human eye to distinguish the changes of the brightness is inversely proportional to the background brightness value to the same signal, the brightness value of the signal background is Larger, the sensitivity of the human eye to it is lower, and The ability to distinguish them is weaker.

In the H.264 encoder, According to different requirements to the video quality, Using 52 large-scale quantization step size, So that the encoder can control the transmission bit rate and quality of the video correctly and flexible. However, in the same video, encoder used the same quantitative criteria to code the high brightness parts and low brightness parts of the signal. As the human visual system to these regions has different sensitivity, which led to the visual redundancy in the part of high-brightness is much greater than in the part of low-brightness, resulting in uneven subjective quality of the video. Therefore, we can adjust the different quantitative criteria of the brightness regions, increase QP in the high-brightness region, and reduce QP in the low brightness region, coarse quantization of the highlighted regions, detailed quantitative of low-brightness regions, adjust the video balance in the subjective quality in different brightness regions. And thus in the condition of did not affect the subjective quality of video, to improve the video compression ratio, Or in the case of maintaining the same bit rate to improve video subjective quality.

3. Realization of Coding Model Based on Visual Perception

3.1 Realization in Coding Side

In the H.264 encoder, the DC coefficient's transform and quantization of luminance component conducted in the 4×4 internal macro blocks [10]. In the configuration file, the quantitative step is given based on the prior actual requirement. As the human visual system's sensitivity to high-brightness regions is lower than low-light district, therefore, we can adjust the quantization step size of different brightness regions to balance the visual redundancy of different brightness regions, in order to achieve the purpose of raising the compression ratio without compromising the subjective quality of video.

According to theory, we should adjust the QP based on the JND which is corresponding to different brightness values. But because of the limitations to the human visual system's understanding of and complexity of the algorithm, we are temporarily unable to determine the way of how to adjustments the specific QP accurately from the theory. Therefore, we choose to pass the test to determine the QP adjustment method. In order to facilitate project implementation, we have divided the brightness of the video into N grades in the experiment. N is set as 2^n (n=1,2,3), n is main determined by the experimental test data. QP is unchanged in the faintest brightness regions, the brightness of a single enhanced for each grade, QP plus 1. Through a large number of experiments, we found that when n=3, effects of the improved decoding algorithm are basically the same as the standard encoder, coding rate have been greatly reduced at the same time. Of course, division the levels of the brightness range and the adjustment settings of QP can be continuous improvement in the future depth research, in order to achieve the best balance between the subjective feeling and the compression efficiency. Specific process is shown in the following figure (Figure 2).

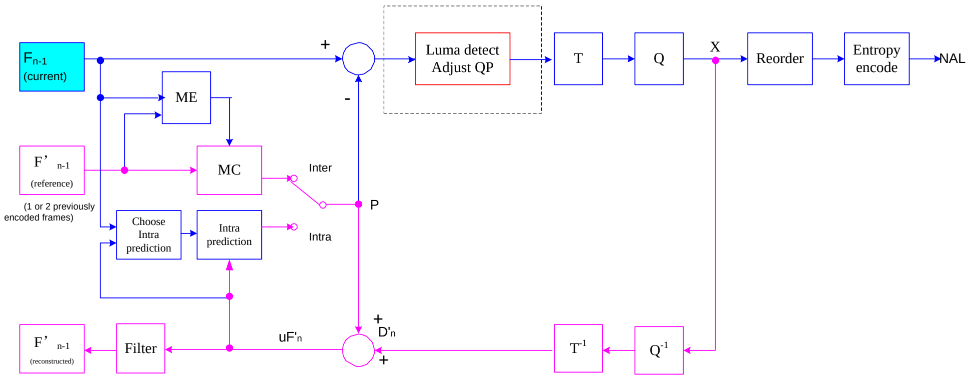


Figure 2. H.264 Decoder Structure Based on Variable Step Size

3.2 The Quantization Step Detection Algorithm in Decoder

In the decoding process, need to use quantitative step size for inverse quantization computing, however, brightness information of decoded pixel cannot be obtained in advance, therefore, we propose an algorithm for seeking the adoption of the original quantization step size by an iterative method.

First of all, QP were taken pre-set default values, using default QP for inverse quantization and inverse transform operations, and calculate the brightness value of macro-block decoding. If the income brightness does not meet the brightness which corresponding to the QP, QP plus 1, repeat the above operation, If the income brightness is in line with the brightness which is corresponding to QP, then the operation is over, the result was obtained from inverse quantization and inverse transform which is we asked for.

Specific process is shown in the following figure (Figure 3).

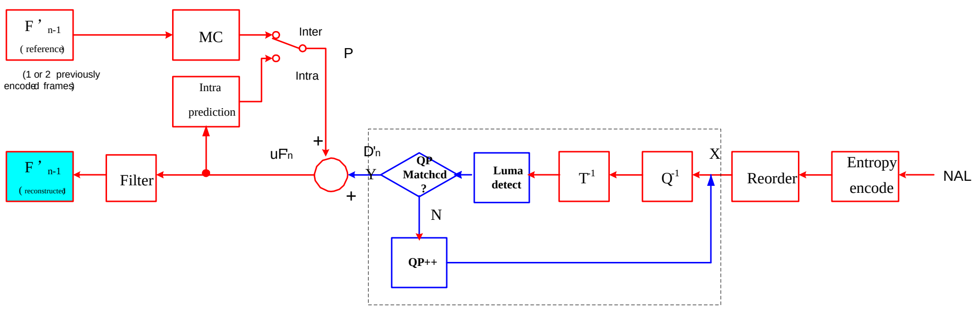
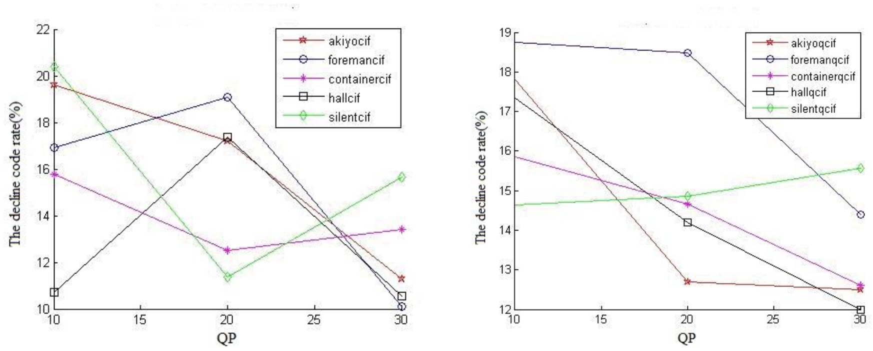


Figure 3. H.264 Decoder Structure Based on Variable Step Size

4. Experimental Result and Analysis

The algorithm has been achieved in the standard of H.264 reference software JM86. In this study, the experiment has been tested on five pairs of video sequences, such as foreman and so on, in the format of CIF and QCIF. In the experiment, encoding 30 frame for each sequence, coding sequence structure is IBPBPBI…, frame rate is 30fps, QP were taken 10, 20, 30, statistic the test results, and compare with the results of H.264 reference software JM8.6. Statistical results were shown in Figure 4: in which the horizontal axis is QP value, the vertical axis is the decline rate of comparing the bit rate of using of this algorithm encoder and the original h.264 encoder. The figure reflects that compare with the standard encoder, using this algorithm encoder the bit rate declined in 10% -20%.



(a) Test Results of 5 CIF Format Sequence (b) Test Results of 5QCIF Format Sequence

Figure 4. Test Results

The encoder which used this algorithm can reduce the bit rate, it is also can ensure that the subjective test results of the decoder side will not be significantly decreased at the same time. Figure 5 shows the improvement of the standard h.264 encoder and encoder h.264 decoding on the part of the video sequence comparison of results.

(a) (b)

(a)QP=10, No. 0 (I-Frame) of Akiyo_Cif Serial h.264 Decoding Map(253544bit) (b)QP=10, No. 0 (I-Frame) of Akiyo_Cif Serial h.264 Improved Algorithm Decoding Map (221224bit)

(c) (d)

(c)QP=20, No. 10 (P-Frame) of Container_Cif Serial h.264 Decoding Map (38640bit) (d) QP=20, No.10 (P-Frame) of Container_Cif Serial h.264 Improved Algorithm Decoding Map (34240bit)

(e) (f)

(e)QP=30, No. 15 (B-Frame) of Foreman_Cif Serial h.264 Decoding Map (2760bit) (f)QP=30, No.15 (B-Frame) of Foreman_Cif Serial h.264 Improved Algorithm Decoding Map (2232bit)

Figure 5. The Comparison Chart of the Subjective Effects in Video Decoder Side

In the subjective test, We use the DSCQS (The Double Stimulus Continuous Quality Scale) method which is a digital video subjective quality assessment criteria ITU-R BT.500-10 developed by VQEG (Video Quality Expert Group on Evaluation) [11-14], look the decoded video which decode by the standard video as a reference video, divided the video quality which is decoded by the improved decoding algorithm into five grades, as shown in Table 1 [15], in the experimental environment of Requirement. Looking for 10 image processing-related professionals and 10 non-professional staff to observe and decode scoring of the 10 group videos.

Table 1. ITU-R Quality and Impairment Scales

Quality	Impairment Scales
5 Excellent	Imperceptible
4 Good	Perceptible, but not annoying
3 Fair	Slightly annoying
2 Poor	Annoying
1 Bad	Very annoying

Table 2 shows the results of 10 video sequences rating, which shows that most people recognized the effect of the improved decoding algorithm. Therefore, we can believe that this improved algorithm can improve the compression ratio, and will not affect the subjective effects of video sequences at the same time.

Table 2. The Subjective Rating Scale of Test Sequence

Sequences	Quality
akiyo_cif	5
akiyo_qcif	5
foreman_cif	4.75
foreman_qcif	5
container_cif	5
container_qcif	5
hall_cif	5
hall_qcif	5
silent_cif	5
silent_qcif	5

5. Conclusion

In this paper, we use the characteristic that the human eye less sensitive to high-brightness region, proposed a simple improved H.264 Algorithm based on a variable step size, coarse quantization of the highlighted regions, detailed quantitative of low-brightness regions, this can balance some of the visual redundancy effectively. This did not affect the subjective quality of video, but can improve the video compression ratio. Experimental results show that the output bit rate was decreased of 10% -20% by using this improved algorithm in H.264 reference encoder, and the subjective quality of decoded image by using this improved algorithm is as good as the standard H.264 encoders. The proposed algorithm is simple, can be applied to other coding standards effectively, applying this algorithm can greatly improve the performance of codec and existing equipment in the practical.

In near future, the authors will move the proposed algorithm to newest encode, *i.e.*, H.265 or AVS 2 to validate its performance and efficiency, and conduct more experimental tests using new video sequence, *i.e.*, HD (high definition) video sequence.

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