

A Video Bit Rate Control Algorithm Based on Weighted Estimate of Image Brightness Difference

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Abstract—Rate control is the core issue to realize video encoder, and it is also one of the key factors determining the quality of video code system. Given the MAD (Mean Absolute Difference) prediction and the drawback of bit rate control in the BU (Basic Unit) layer, improvements are put forward on the basis of analyzing and researching the G012 rate control algorithms in this paper.

In this paper, we proposed a new video bit rate control algorithm to overcome the drawback of bit rate control in the BU (Basic Unit) layer.

Combined with the image brightness gradient value to estimate in the MAD prediction, the allocation encoding bits method based on the PSNR (Peak Signal to Noise Ratio) is proposed in the rate control of BU layer. The experiment results show that compared with JM algorithms in H.264 standard reference software, the improved algorithm is enhanced in the PSNR.

Keywords—H.264; Basic Unit; Mean Absolute Difference; Peak Signal to Noise Ratio

I. INTRODUCTION

As an important part of video coding, the main task of rate control (RC) is to control output data stream of video encoder effectively and to gain the optimal video decoding quality in the decoder as far as possible, so the video rate control has been a research hotspot in video coding domain. Researchers proposed a lot of corresponding rate control schemes, among which TM5 of mpeg-2, VM8 of MPEG-4, TMN8 of H.264 algorithms and so on are the relatively classic schemes.

At present, H.264 is the most widely used video coding international standards. Compared with the previous video compression standards, H.264 standard can achieve high quality and low rate coding. The corresponding rate control schemes, such as JVT-F086, JVT-G012^[1] and so on, among them, JVT-F086 is stem from the improvement of TM5 algorithm, JVT-G012 achieves satisfying results in the aspect of H.264 rate control. However, the shortcoming of JVT-F086 is that when the video sequences have fast movements or scene changes, the MAD fluctuations occur extremely among frames. These fluctuations cause the great differences in MAD value between the linear MAD prediction model and the actual value. The irregular frame data join in updating the prediction model parameters can cause the failure of the model. Additionally, in dealing with the bit allocation of the basic unit of P frames, the algorithm

failed to take into account the complexity size of all the basic units, which is easy to cause fluctuations of the frame image.

Myoung Jim etc^[2] use the frame complexity to predict MAD in order to make the bit allocation of each frame connected with frame rate and frame complexity. Chenjuan Hou etc^[3] use correlation predicting method of the adjacent macro block to predict MAD. Experiments show that this method achieves rather satisfying effects in the forecasting precision, but the good results are obtained at the cost of algorithm complexity. Wu Yuan^[4] adopt the bit distribution solutions of linear model and the quadratic model, by which the effectiveness of rate distortion model is improved. When the image content transformation is relatively high, allocation scheme of G012 algorithm can lead to extreme difference exists between the estimation target bits number and actual output number, and even bring sharp fluctuations to the image quality. What's more, sharp fluctuations between two adjacent frames have a serious impact on the subjective quality of the video^[5]. In order to solve the problems, this paper proposed a weighted brightness gradient-based rate control algorithm, which has avoid the quality decline of video encoding and decoding caused by severe fluctuations of the image.

II. JVT-G012 ALGORITHM AND IMPROVEMENTS

A. The traditional G012 algorithm

Rate control scheme of G012 standard divided the video into three layers, GOP (Group of Pictures) layer, frame layer and BU (Basic Unit) layer.

Coding bit flow and decoding method in the H.264 standard draft occupy the central position. In the H.264, QP is used both in rate control algorithm and Rate-distortion Optimization (RDO)^[6], as is shown in Fig.1:

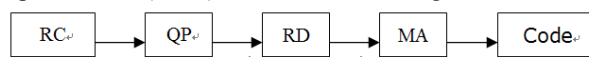


Fig.1 Macro block level coding flow chart

From Fig.1 we can see, when the bit rate control is to be implemented, in order to do RDO to the current macro block, the QP value of the current block is needed to be gotten, which relies on the MAD value of the current macro block. However, the MAD of the current macro block can only be obtained only through doing RDO to the current

macro block. So, this could cause a well known chicken and egg dilemma.

G012 algorithm uses the method of predicting MAD value to solve the above problems, which uses a linear model to predict the MAD value of basic unit in current frame, and its reference is the MAD value of corresponding basic unit in the previous frame. It is assumed that the current MAD value of basic unit in current frame is MAD_{cb} , while the MAD value of basic unit in the previous frame is MAD_{pb} , so the linear forecasting model can be expressed as follows:

$$MAD_{cb} = a_1 \times MAD_{pb} + a_2 \quad (1)$$

which a_1 and a_2 are two parameters of the forecasting model, and its initial value respectively were set to 1 and 0. When the coding of each basic unit finished, the value of a_1 and a_2 will also be updated accordingly.

According to the concept of basic unit and the linear forecasting model based on MAD, the specific steps of G012 algorithm are as follows:

The first step: to calculate target figures of the current frame;

The second step: to distribute averagely remaining figures to not coding basic unit of the current frame;

The third step: according to the actual MAD value of reference position basic unit in the previous frame, to predict MAD value of the current basic unit based on the linear forecasting model.

The fourth step: using bigram R-D model [7-8] to calculate the corresponding parameter values.

The fifth step: using the parameter value gotten from the fourth step [9-10] to realize RDO of each macro block in the current basic unit.

B. Improvement of the MAD forecasting model

Given using the MAD prediction scheme of G012 rate control algorithm to deal with video sequence of relatively quick scenery changes, which causes the great differences between predicted MAD value and the actual MAD value, so, this paper proposes a weighted budget method based on image brightness difference. The basic idea is that firstly we can calculate brightness gradient values of the current coding frame and previous frame and use it as the weight values, after that we can predict MAD values through the (2) formula together.

$$MAD_{cbnews} = \frac{a_1 * MAD_{pbnews} + a_2 + \rho * MAD_{pbnews}}{2} \quad (2)$$

$$\rho = \sum_{k=(j-1)*N_{mbunit}}^{j*N_{mbunit}} \frac{|y(i, j, k) - y(i-1, j, k)|}{y(i-1, j, k)} \quad (3)$$

ρ is the Brightness gradient value of the same position macro block between the i -th P frames, the j -th BU, the k -th macro block and the previous frame in the current GOP, $y(i, j, k)$ is the brightness values of the current position, MAD_{cbnews} is the MAD value of the current basic unit, MAD_{pbnews} is the MAD value of the corresponding place of the previous frame, the definition of N_{mbunit} can be seen in

the third quarter. Among them, ρ reflects brightness changes degree of the current BU layer in the inter-frame, the greater the change, the bigger the difference of the inter-frame.

III. PSNR- BASED BU LAYER ASSIGNMENT ALGORITHM

Assume that a frame image consists of N_{mbpic} macro blocks, a basic unit is composed by a continuous N_{mbunit} macro blocks, among that N_{mbunit} is part of the N_{mbpic} 's, the total number of a basic unit is N_{unit} , so:

$$N_{unit} = \frac{N_{mbpic}}{N_{mbunit}} \quad (4)$$

The basic unit of a macro block may be a slice or a field or a frame. For example, considering a video sequence whose size is QCIF, N_{mbpic} is 99, it can be learned from the image structure, N_{mbpic} can be 1,3,9,11,33 or 99, and the corresponding N_{unit} can respectively be 99,33,11,9,3 or 1.

G012 algorithm uses the average allocation method to allocate the bit number of the basic unit, without taking into account the complexity of the images. Thus, an allocated method based on the PSNR (Peak Signal to Noise Ratio) of the previous frame is proposed in this paper. View PSNR as a parameter to measure image complexity, the PSNR values of the basic unit of the previous frame is used to estimate the complexity of each basic unit in the current frame, and to allocate bits for the corresponding basic units of the current frame. The specific algorithm description is as follows:

The first step: to calculate the average peak signal to noise ratio $PSNR_{av}$ of the frame prior of the current coding frame by formula (5). In the formula (5), $PSNR_{i-1}^k$ is the PSNR values of the k -th basic unit in the $(i-1)$ -th frame;

$$PSNR_{av} = \frac{\sum_{k=1}^{N_{unit}} PSNR_{i-1}^k}{N_{unit}} \quad (5)$$

The second step: to calculate α_{i-1} by formula (6), α_{i-1} is a fluctuation coefficient of a basic unit PSNR in the $(i-1)$ -th frame, the value of PSNR of the k -th basic unit in the $(i-1)$ -th frame is $PSNR_{i-1}^k$;

$$\alpha_{i-1} = \frac{\sum_{k=1}^{N_{unit}} |PSNR_{i-1}^k - PSNR_{av}|}{PSNR_{av} * N_{unit}} \quad (6)$$

The third step: to calculate the allocated number of bits of each basic unit, according to the first step to calculate the $PSNR_{av}$ value, to calculate the allocated number of bits of the current basic unit. When $PSNR_{i-1}^k$ is greater than $PSNR_{av}$, the k -th basic unit should allot the number of bits by equation $R_{bu}^k = T * (1 + \alpha_{i-1}) / N_{unit}$; when $PSNR_{i-1}^k$ is less

than $PSNR_{av}$, k-th basic unit allot the number of bits in accordance with the formula $R_{bu}^k = T * (1 - \alpha_{i-1}) / N_{unit}$; when $PSNR_{i-1}^k$ is equal to $PSNR_{av}$, k-th basic unit allot the number of bits in accordance with the formula $R_{bu}^k = T / N_{unit}$, among that R_{bu}^k is the number of bits allotted of k-th basic unit in the current frame.

The improvement rate control process combined with the weighted prediction MAD value of the brightness gradient and the BU layer bit allocation scheme based on PSNR is as follows:

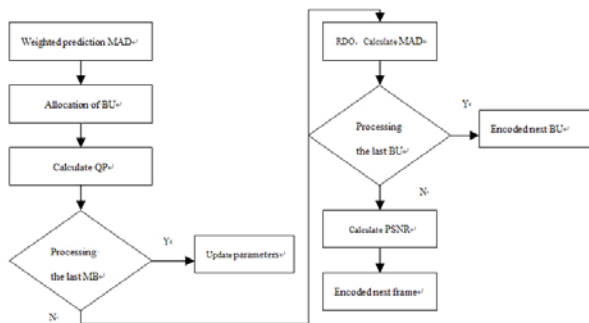


Fig.2 Frame-level rate control process

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In this section, we compare the new algorithm with the G012 rate control algorithm in the standard proposal. The test sequences are FOOTBALL and bridge-close standard OCIF video sequence, which have different scenery changing speeds, the sequence structure is IPPP..., the total coding frames are 100, the frame rate is 30 per second. FOOTBALL sequence is a football scene, which has fast scenery changes; bridge-close is the description of a bridge, the images change not so fast. Compared the algorithm proposed in this paper with the G012 algorithm, the testing results are as follow:

Table.1 Test results of two algorithms

| average PSNR | FOOTBALL video sequences | | | bridge-close video sequences | | |
|------------------|--------------------------|---------------|----------|------------------------------|---------------|----------|
| | (PSNR/db) | | | (PSNR/db) | | |
| | G012 | New algorithm | Increase | G012 | New algorithm | Increase |
| Y component | 35.40 | 37.56 | 2.16 | 38.17 | 39.06 | 0.89 |
| U component | 35.44 | 36.94 | 1.50 | 36.70 | 37.31 | 0.61 |
| V component | 34.29 | 35.69 | 1.40 | 35.67 | 36.53 | 0.86 |
| Integrated value | 35.04 | 36.73 | 1.69 | 36.85 | 37.63 | 0.79 |

As can be seen from Table 1 of the test results, the average PSNR obtained through encoding video sequences by the algorithm of this paper and the G012 are different, the PSNR Y,U,V components of the former algorithm are higher than the latter one, the difference value are 2.16、

1.5、1.4 (FOOTBALL video sequence) ,0.89、0.61、0.86 (bridge-close video sequence) respectively. When encoding the bridge-close video sequence, the average PSNR obtained through the algorithm of this paper is 0.79 higher than that gotten through the G012 algorithm, when in the FOOTBALL video sequence, because of the fast scenery changes, that corresponding number is 1.69. PSNR function as one of the main judge standards of objective video quality, the experiment data show that compared with the G012 algorithm, the algorithm proposed in this paper achieved better video quality. At the same time, it can be seen from the analysis of the 9 frame data random selected from the tested data (fig.3), the PSNR gotten through the algorithm of this paper is higher than that of G012. What's more, when adopting the G012 algorithm in the FOOTBALL video sequence which has relatively fast scene changes, the gotten PSNR has greater fluctuations, which is easy to create violent video fluctuations. So the algorithm of this paper shows prominent advantages when controlling bit rate of scenes that has relatively fast scenery changes.

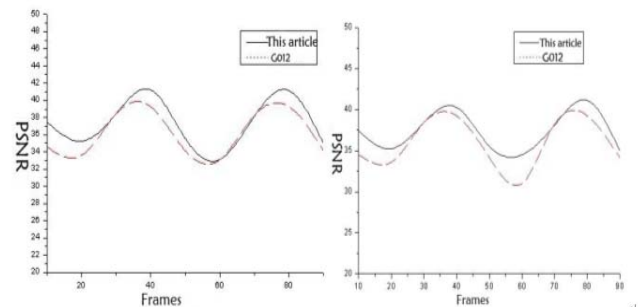


Fig.3 Code results comparison

V. CONCLUSIONS

By analyzing the standard G012 rate control algorithm and improving the linear prediction model of MAD, a brightness-weighted prediction model is designed in this paper. The new model makes full use of the temporal and spatial relationship of the image sequence, prediction accuracy is improved. This paper presents an allocation scheme based on the PSNR of the previous frame which can effectively avoids the image fluctuations caused by the different image complexity in the same frame. The test results show that the average PSNR of the new algorithm is bigger than G012 in the condition that the video structure is complex and changes fast. Additionally, the encoded PSNR value of new algorithm in the BU layer bit allocating is higher than that of the G012 algorithm.

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