

## SYSTEM AND METHOD OF BIT ALLOCATION IN SCENE CHANGE SITUATIONS

### FIELD OF THE INVENTION

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The present invention relates to bit allocation and rate control in a video encoding system. Particularly, the invention relates to a method of bit allocation following a scene change in a video data sequence.

### 10 BACKGROUND OF THE INVENTION

To minimise implementation complexity, the bit allocation scheme in the MPEG-2 Test Model-5 (TM-5) makes use of a complexity measure of a present picture of a certain type (I, P, or B) to estimate the target bit allocation of the next picture of the same type. After a  
15 picture of a certain type (I, P, or B) is encoded, the respective "global complexity measure" ( $X_i$ ,  $X_p$ , or  $X_b$ ) is updated as:

$$X_i = S_i Q_i \quad (1)$$

$$X_p = S_p Q_p \quad (2)$$

$$20 \quad X_b = S_b Q_b \quad (3)$$

where  $S_i$ ,  $S_p$ ,  $S_b$  are the number of bits generated by encoding this picture and  $Q_i$ ,  $Q_p$ , and  $Q_b$  are the average quantization parameters computed by averaging the actual quantization values used during the encoding of all the macroblocks, including skipped macroblocks.

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The target number of bits ( $T_i$ ,  $T_p$ , or  $T_b$ ) for the next picture in a group of pictures (GOP) is computed as:

$$T_i = \max \{ R / (1 + N_p X_p / X_i K_p + N_b X_b / X_i K_b), \text{bit\_rate} / (8 * \text{picture\_rate}) \} \quad (4)$$

$$30 \quad T_p = \max \{ R / (N_p + N_b K_p X_b / K_b X_p), \text{bit\_rate} / (8 * \text{picture\_rate}) \} \quad (5)$$

$$T_b = \max \{ R / (N_b + N_p K_b X_p / K_p X_b), \text{bit\_rate} / (8 * \text{picture\_rate}) \} \quad (6)$$

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where:

$K_p$  and  $K_b$  are "universal" constants dependent on the quantization matrices;

$N_p$  and  $N_b$  are the number of P-pictures and B-pictures remaining in the current GOP in the encoding order;

5  $R$  is the remaining number of bits assigned to the GOP; and  $R$  is updated after encoding a picture, as follows:

$$R = R - S_{i,p,b}$$

10 where  $S_{i,p,b}$  is the number of bits generated in the picture just encoded (depending on whether the picture is I, P, or B).

Before encoding the first picture in a GOP (an I-picture):

$$R = G + R$$

15  $G = \text{bit\_rate} * N / \text{picture\_rate}$

$N$  is the number of pictures in the GOP

At the start of the sequence  $R = 0$ .

20 The TM-5 bit allocation method is described fully in "International Organisation for Standardisation ISO-IEC/JTC1/SC29/WG11: Coded Representation of Picture and Audio Information, Test Model 5".

25 In the TM-5 bit allocation method, using the current picture complexity to estimate the next picture bit allocation gives rise to inaccuracies when a scene change occurs in the next picture.

30 The bit allocation method used in TM-5 to calculate the target number of bits for the next picture is based on the global complexity measure ( $X_i$ ,  $X_p$ , and  $X_b$ ) of the current picture, which can result in an inaccurate prediction of the target number of bits when a scene change occurs. Referring to Figure 2, when a scene change occurs, the complexity measure,  $X_{p1}$ , of the next P-picture ( $P_1$ ) after the scene change will normally be higher.

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But since the target number of bits for the P-picture after the scene change is based on the complexity measure of the P-picture before the scene change, the target bits for P1 may be inaccurately predicted. Likewise for the P-picture following P1, the target will be inaccurately predicted as being much higher due to the high complexity measure of P1 being used. The effect of this is that a degradation of picture quality in the several pictures after the scene change will propagate from the encoding error in the first P-picture. To address the problems associated with the scene change situation, an intra-encoding mode can be used to encode a picture which includes a new scene, such as described in US patent no. 5,532,746. When a scene change is detected in a P-picture, the picture is allocated with bits corresponding to the intra-coded picture and the picture is coded in an intra-mode. In US patent no. 5,832,121, the start of a GOP is determined by detecting a new scene in order to intra-frame code the new scene. These kinds of methods do not have a fixed number of pictures in a GOP during encoding of a sequence, and are not suitable to use for an encoder system which requires a fixed number of pictures in a GOP.

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Some methods avoid picture degradation in the scene change situation by allocating more bits to encode the new scene picture. In US patent no. 5,7318,35, when a scene change occurs, extra bits are allocated to encode the picture, where the number of bits depends on 1) the distance of the P-picture that is about to be coded from the end group of pictures; 2) the number of I-mode macroblocks in the P-picture; 3) ease of coding the I-mode macroblocks in the P-picture; and 4) the number of bits presently in the video buffer verifier (V BV). In this method, the situations where multiple scene changes occur close together may require a significant number of extra bits, and as the extra number of bits is only limited by the potential of a V BV underflow occurrence, it could increase the chance of panic-mode encoding. In panic-mode encoding, only the minimum amount of data required to maintain the integrity of the bitstream is transmitted, which significantly degrades the picture encoding quality.

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In US patent no. 5,617,150, SUBGOPs are defined as sets of 2-4 frames in a GOP, and if a scene change is found in a subsequent SUBGOP, bit allocation adjustment is made to save bits in the current SUBGOP, and when a scene change is found in the current SUBGOP,

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extra bits are assigned to the current SUBGOP. As this method requires detection of a scene change in a subsequent SUBGOP before bits assignment, there is an undesirable encoding latency. Also, as bits are saved in the current SUBGOP so as to be used in next SUBGOP, it is only suitable for constant bit-rate applications, as using bits saved from  
5 previous pictures is not necessary in variable bit-rate applications.

When a scene change occurs, the first P-picture after the scene change will generally be difficult to encode and will need more bits because of the intra-mode coding required. B-pictures are not affected as much due to the usual bi-directional motion estimation thereof.  
10 In addition, because the error in the P-picture will propagate, it is important to minimise the degradation in quality of the first P-picture after a scene change.

It is an object of this invention that the above inaccurate bit allocation estimation problems of TM-5 are addressed by correcting the picture complexity value that is used to estimate  
15 the bit allocation for the next picture, or that it at least provides a useful alternative. This inaccuracy problem applies to the two subsequent P-pictures that follows the scene change as both of these P-pictures have inaccurate picture complexity values used for their bit allocation assignment. By adjusting the picture complexity value following the scene change detection to give a more accurate bit allocation to the two P-pictures after the scene  
20 change, this method can be used for encoder bit-rate control for both constant bit-rate and also variable bit-rate schemes. It should be noted that reducing the bit allocation for other pictures to compensate for the increase in bit allocation for scene change is not necessary for variable bit-rate applications.

25 It is noted that for multiple scene changes close together, for example scene changes which occur every 2 to 3 frames, the increased target bit allocation for every scene change is not realistic in constant bit-rate applications. Also, human visual acuity is generally not able to sensibly interpret such an apparently 'continuous' scene change.

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## SUMMARY OF THE INVENTION

The present invention provides a method of bit allocation for use in a video encoding system adapted to encode video data representing a group of pictures (GOP), the method  
5 including the steps of:

- processing said video data to detect a scene change within the GOP;
- increasing a first picture complexity value of a first P-picture in the GOP to be encoded following detection of the scene change by a predetermined factor;
- determining a first target bit allocation for encoding the first P-picture based on the  
10 increased first picture complexity value; and
- allocating a first number of bits for encoding the first P-picture based on said first target bit allocation.

The present invention further provides a video encoding system adapted to encode video  
15 data including a group of pictures (GOP) the system including:

- a scene change detection module for detecting a scene change within the GOP;
- a picture complexity module for increasing a first picture complexity value of a first P-picture in the GOP to be encoded following detection of the scene change by a predetermined factor;
- 20 a bit allocation module for determining a first target bit allocation for encoding the first P-picture based on the increased first picture complexity value and allocating a first number of bits for encoding the first P-picture based on said first target bit allocation.

Preferably, operation of the picture complexity measurements and the bit allocation  
25 estimation is similar to the MPEG-2 TM-5 when there is no scene change detected, yet when a scene change is detected, the picture complexity that is to be used to compute the bit allocation of the subsequent two P-pictures after the scene change is adjusted so that their bit allocation is more accurately estimated.

30 It is considered that an increased target bit allocation for every scene change in a close

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multiple scene change situation is unnecessary and inefficient for constant bit-rate application, so preferably the above picture complexity adjustment is only applied to scene changes that are at least a certain period of time apart. For example, if the number of frames in between two scene changes is less than a pre-determined value, then the picture  
5 complexity adjustment is not done.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of a video encoding system;

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Figure 2 is an illustration of a group of pictures in which there is a scene change adjustment;

Figure 3 is a flow diagram of a complexity measure adjustment process executed by a  
15 picture complexity adjustment module of the video encoding system.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A video encoder system, as shown in Figure 1, includes a complexity computation module  
20 101, a complexity adjustment module 102, a bit allocation and rate control module 104, an encoder 105, a video data input source 106 and a scene change detector module 103. The scene change detector 103 is adapted to analyse the video input data from video input source 106 to detect scene changes within that video input data and to provide a scene change output signal to the complexity adjustment module 102 upon detection of a scene  
25 change. The complexity computation module 101 determines a complexity computation measure for each I, P or B-picture in a GOP based on feedback from the bit allocation and rate control module 104. The complexity computation module 101 outputs the respective complexity measures for the I, P and B-pictures, based on equations (1), (2) or (3), to the complexity adjustment modules 102, whereupon if a scene change output signal has been  
30 received, the complexity measure for the first P-picture detected immediately after the scene change is increased by a factor M. If it is the second P-picture detected after the

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scene change signal was received, the complexity measure of the second P-picture is decreased by the factor M, or optionally by a different factor K. The complexity measures, with the adjusted P-picture complexity measure, are then passed to the bit allocation and rate control module 104 for bit allocation (according to equations (4), (5) or (6) as appropriate) prior to encoding of the picture by the encoder 105.

Referring to Figure 2, in the MPEG-2 TM-5 model, the picture complexity value  $X_{p0}$  of picture  $P_0$  is normally used for calculating the target number of bits ( $T_{p1}$ ) for picture  $P_1$ , based on the assumption that the picture complexity  $X_{p0}$  is close to  $X_{p1}$ . This assumption is false if a scene change is detected between  $P_0$  and  $P_1$ . Therefore, in embodiments of the invention, to make the target bit allocation  $T_{p1}$  of picture  $P_1$  more accurate, the value  $X_{p0}$  is increased for the computation of  $T_{p1}$  so as to increase the target bits allocation. The value of  $X_{p1}$  is expected to be high due to the scene change, and it would not be accurate to use it for estimation of the target bit allocation of the second P-picture,  $T_{p2}$ , so the value of  $X_{p1}$  is reduced prior to the computation of  $T_{p2}$ .

Figure 3 shows the detailed flow diagram of a preferred method for picture complexity adjustments in the complexity adjustment module 102. The method is executed for each picture in a GOP. If a scene change is detected at step 300 and a P-picture is to be encoded (step 301), the distance between the current scene change and the previous scene change, is checked at step 303, to see if it is greater than a threshold D. If the distance is greater than D, the picture complexity  $X_p$  of the P-picture before the scene change (computed in complexity computation module 10 after it is encoded) is increased at step 304 by a factor M before the target bit allocation is computed. A previous scene change flag (prev\_SC\_flag) is then set at step 305 so that in the subsequent P-picture, the picture complexity is reduced (step 311) by the factor M before the target bit allocation is computed. If scene change occurs before an I-picture and after the last P-picture of the GOP is checked at step 302, the picture complexity of the P-picture after the scene change is not adjusted as it is not necessary. A scene change flag (scene\_change\_flag) is set by the scene change detector 103 whenever a scene change is detected and it is only reset by the complexity adjustment module 102, in step 306. Once the scene change flag is reset,

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the distance counter D is also reset at step 307. If the picture is a B-picture or the scene change flag is not set, the distance counter D is incremented at step 308.

If the scene change flag is not set but the previous scene change flag is set (step 309), then if the picture is a P-picture (step 310), the complexity measure for that picture is reduced  
5 by the factor M or K at step 311 and the previous scene change flag is reset at step 312.

The values of M and K can be of an experimentally determined fixed value, for example values of 2 and 1.5. The distance threshold value D can be a predetermined value such as 10 or 15.

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Advantageously, the present invention is able to correct the inaccurate bit allocation of the TM-5 model when a scene change occurs, such that the corrected bit allocation for the two subsequent P-pictures results in a better picture quality. The invention can be applied to both constant bit-rate and variable bit-rate control and there is no latency as it does not  
15 require checking future pictures to determine whether a scene change occurs.

Advantageously, the invention avoids the situation of unnecessarily allocating extra bits because of multiple scene changes that are close together and the chance of panic-mode encoding due to potential VBV underflow is reduced.

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## CLAIMS:

1. A method of bit allocation for use in a video encoding system adapted to encode video data representing a group of pictures (GOP), the method including the steps of:  
5 of:  
processing said video data to detect a scene change within the GOP;  
increasing a first picture complexity value of a first P-picture in the GOP to be encoded following detection of the scene change by a predetermined factor;  
determining a first target bit allocation for encoding the first P-picture based  
10 on the increased first picture complexity value; and  
allocating a first number of bits for encoding the first P-picture based on said first target bit allocation.
2. A method according to claim 1, wherein the method of bit allocation is for use in a  
15 constant bit-rate video encoding system.
3. A method according to claim 2, wherein the method further includes the steps of:  
before said increasing step, determining a distance value representative of  
the distance between the detected scene change and a previously detected scene  
20 change; and  
performing said increasing step only if the distance value is greater than a predetermined distance threshold value.
4. A method according to claim 1 or claim 3, wherein the method further includes the  
25 steps of:  
decreasing a second picture complexity value of a second P-picture in the GOP to be encoded following detection of the scene change by the predetermined factor;  
determining a second target bit allocation for encoding the second P-picture  
30 based on the decreased second picture complexity value; and  
allocating a second number of bits for encoding the second P-picture based

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on said second target bit allocation.

5. A method according to any one of the preceding claims, wherein the method of bit allocation is performed in an implementation of the MPEG-2 Test Model 5 bit allocation scheme.  
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6. A video encoding system adapted to encode video data including a group of pictures (GOP) the system including:  
a scene change detection module for detecting a scene change within the  
10 GOP;  
a picture complexity module for increasing a first picture complexity value of a first P-picture in the GOP to be encoded following detection of the scene change by a predetermined factor;  
a bit allocation module for determining a first target bit allocation for  
15 encoding the first P-picture based on the increased first picture complexity value and allocating a first number of bits for encoding the first P-picture based on said first target bit allocation.
7. A system according to claim 6, wherein the system is a constant bit-rate video  
20 encoding system.
8. A system according to claim 7, wherein the picture complexity module is further adapted to determine a distance value representative of the distance between the detected scene change and a previously detected scene change, and adapted to  
25 make a comparison of the distance value and a predetermined distance threshold value whereby the complexity value of the first P-picture is only increased if the distance value is greater than the predetermined distance threshold value.
9. A system according to claim 6 or claim 8, wherein the picture complexity module is  
30 further adapted to decrease a second picture complexity value of a second P-picture in the GOP to be encoded following detection of the scene change by the

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predetermined factor; and the bit allocation module is further adapted to determine a second target bit allocation for encoding the second P-picture based on the decreased second picture complexity value and to allocate a second number of bits for encoding the second P-picture based on said second target bit allocation.

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10. A system according to any one of claims 6 to 9, wherein the system is adapted to implement the MPEG-2 Test Model 5 bit allocation scheme.

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