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Rate Control Scheme for Multi-User VBR Communication System

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Abstract—The study of rate control problem in variable bit rate (VBR) video coding system while considering the point to point cases, in which the rate control problem may often abstracted as how to allocate bits among different frames or blocks while available bandwidth is limited. In some other cases, such as some wireless ATM systems, multi users share the common limited bandwidth. In such conditions, the bandwidth allocation among different users becomes a rather important problem. In this paper, a rate control scheme is presented, where the available bandwidth is dynamically allocated among different users based on an equal distortion criterion. Simulated result show that the proposed scheme considerably improves the overall subjective performance in multi-user variable bit rate communication systems. It is noticed that the proposed join source and channel rate control idea is a very general concept that can be useful in many similar problems.

Key words: *variable bit rate; rate control; bandwidth allocation*

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I. INTRODUCTION

In recent years, multimedia communication has developed rapidly, where rear time video is getting more and more important. Rate allocation for a single user has been well investigated in the literature. In single-user rate allocation, the task of the rate controller is to assign the available rate to each frame and each macro block to achieve the maximal visual quality. This is also known as rate control. The simplest rate control method is the constant bit-rate allocation (CBR), which equally allocates the bit-rate to each frame. However, CBR often results in quality fluctuation, due to which the overall visual quality is significantly degraded. To overcome this problem, variable bit-rate allocation (VBR) is proposed, (VBR) is one of the key features of video source coding. So bandwidth allocation and rate control play important roles in these systems. Much work has been done to study the rate control problem in VBR video coding systems. While most of them consider the point-to-point cases, where the rate control problem can be abstracted as how to allocate bits among frames or among blocks when available bandwidth is given. In this field, different schemes have been proposed according to different goals of rate control. For example, some schemes try to accurately achieve the target bit rate; some schemes try to avoid overflow and underflow in output buffer. However, in some other cases, such as the wireless ATM system, more than one user share the common bandwidth. In such cases, the first problem to handle is the bandwidth allocation among different users. This difference on rate control is shown by diagram in Figure 1.

A promising forward rate control scheme has been proposed, which fairly allocates bits among macro blocks to achieve subjectively high image quality. The word fairly means that all reconstructed macro blocks will have approximately the same subjective quality. More bits are assigned to complex macro blocks, and fewer bits are assigned to simple macro blocks. In the following section, this idea is extended to multi user cases. We propose a novel bandwidth allocation scheme, dynamically allocate bandwidth among different users.

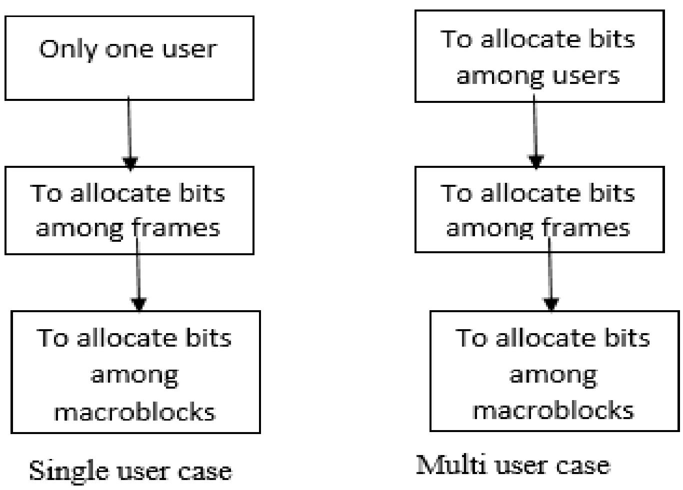


Figure 1. COMPARISON OF RATE CONTROL IN SINGLE USER CASE AND IN MULTI- USER CASE

II. THEORETICAL ANALYSIS

As shown in Fig.2, in our system, we assume that there is a controller, N transmitters, u1, u2,…uN and N receivers,r1,r2,…rN . User *ui* transmits the video sequence *vi* to the corresponding receiver *ri* through a channel/link that is shared by other users u1… ui-1, ui+1,..uN. Since the channel has a limited bandwidth, it may not be able to satisfy the band-width requirements for all users. The role of the controller is to allocate the channel bandwidth to users u1, u2…uN.

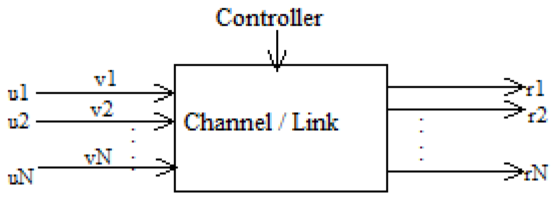


Figure 2. SYSTEM MODEL

A theoretical analysis is presented on the rate-distortion function of video source in the typical hybrid MC-DCT image coding scheme. It is started from macro block. The statistics [4-6] showed that DCT coefficients in macro block, submit closely to Laplacian distribution:

$$p(x) = \frac{\lambda}{2} e^{-\lambda |x|} \quad \ldots (1)$$

Where $\lambda = 1/E|x|$, and E|x| is the mean value of the absolute DCT coefficients in a macro block.

Distortion measurement is defined as

$$d(x,y) = d(|x-y|) = \delta(\theta) = |\theta|, -Q/2 \le \theta < Q/2 \quad \ldots (2)$$

Above is for absolute value of the quantization error. In eqn.(2) x and y are the values of DCT coefficients before and after quantization respectively. x - y is the quantization error, and Q is the value of the quantization parameter. The rate distortion function for a macro block can be computed approximately as Refs. [4,5]:

$$R = A.log_2^{\left(\frac{E(|x|)}{D}\right)} \text{ (bits per microblock)} \quad \ldots (3)$$

Where D is the distortion measurement and is half of Q, R is the expected number of bits generated when using Q as the quantization parameter, and A is a constant. Assume user n has Mn macro blocks in one frame, then for each macro block, Eq. (3) can be rewritten as:

$$Rnm = A.log_2^{\left(\frac{Enm(|x|)}{Dnm}\right)} \quad ; m=1\ldots Mn \quad \ldots (4)$$

According to the fair distortion criterion, all macro blocks are set to have the same distortion D, so the total rate for user n in one frame can be written as:

$$Rn = \sum_{m=1}^{M} Rnm = A.Mn.\sum_{m=1}^{M} \log_2 Emn(|x|) - A.Mn.\log_2 D$$

$$; n=1\ldots N \quad \ldots (5)$$

Substitute: $a_n = A.Mn.\sum_{m=1}^{M} \log_2 Emn(|x|)$

and b_n=A.Mn ... (6)

Then Eqn. (5) can be rewritten as:

$$Rn = an - bn.\log_2 D \quad \ldots (7)$$

Because the total available bandwidth is N.C

$$N.C = \sum_{n=1}^{N} Rn = \sum_{n=1}^{N} an - \log_2 D.\sum_{n=1}^{N} bn \quad \ldots (8)$$

Then we have

$$\log_2 D = \left(\sum_{n=1}^{N} an - N.C\right) / \sum_{n=1}^{N} bn \quad \ldots (9)$$

From eqn. (7) & (9), we have

$$Rn = a_n - b_n.c_n \quad \ldots (10)$$

Where $cn = \left(\sum_{n=1}^{N} an - N.C\right) / \sum_{n=1}^{N} bn$

From Eqn. (5) to (10) each user can calculate its own Rn that is the bit rate from the given value of D or applied value of D decided by the user.

Thus from this scheme, users having important motions will be granted more bits at the instant, keeping similar distortion for similar image quality among users. For some users the allocation result Rn may be negative according to Eq. (10), when $\sum_{n=1}^{N} an > N.C$ and a_n is small. This is not operable but rational. It means that this user has so little information to transmit that it should not been granted any bandwidth according to the equal-distortion criterion. Since its E|x| is lower than D, they should yield some previously granted bandwidth to others and this is not operable so Rn should be set to zero in this case.

The given scheme is beneficial while comparing the variations of image quality, measured by the variation of D, in the following two cases:

Case I: Each video source is assigned the same bandwidth C for equal bandwidth scheme.

Case II: Allocating the total N.C bandwidth among the N users for mentioned equal distortion criterion.

So, in case I, variable $f1 = \log_2 D = E(x) - \frac{C}{DCTnum.\ M}$ has a variance equals to $\frac{1}{N}\sigma^2$.

It is clear that the image quality variation has considerably decreased when applying the equal distortion rate control scheme instead of equal bandwidth scheme. This implies comparing with case-I for each user, granted bandwidth may vary from time to time, while its image quality will be smoother regardless of the variation on image content;

At any instant, the bandwidth granted to users may be quite different, but the image quality is similar among different users. When N is large, M will be small enough. Each user can achieve almost the same content quality. This is just what should be expected.

III. SIMULATION SYSTEM

In the theoretical analysis in Section 2, there are some approximations in both source model and the process of deduction. It's necessary to make sure if these approximations are significant or not. For this purpose, some computer simulation experiments have been carried out. In this section, the description of the simulation system and the corresponding results are given. In the simulation system, there are eight independent users active in total, each of which is a VBR video source with fixed frame rate coded with MPEG-4. These eight video sources share the common 128 kbit/s bandwidth. Considering the codec delay and buffer delay, 100ms is adopted as the interval to adjust bandwidth allocation, which is noted as bandwidth allocation window. In each window, each user reports its bandwidth request by acknowledged rate distortion function. The diagram of the simulation system is given in Figure 3.

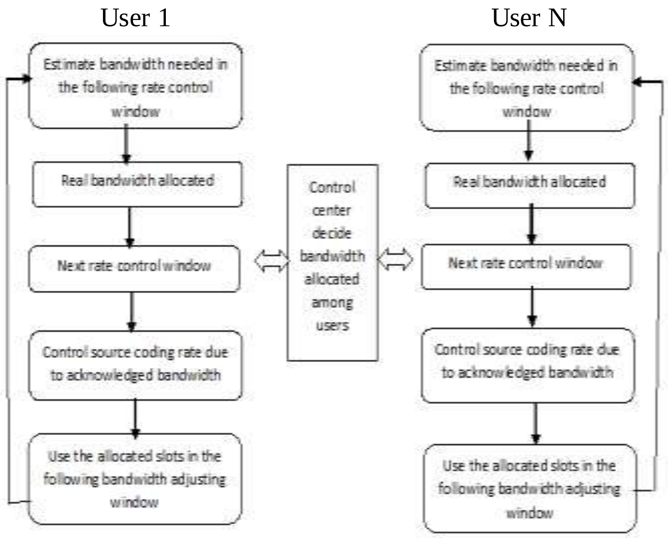
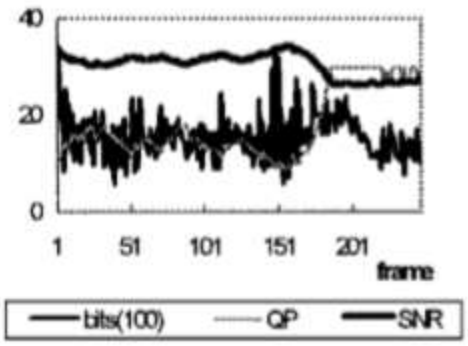
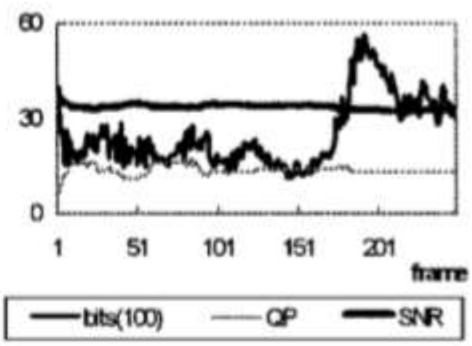


Figure 3. DIAGRAM OF THE SIMULATION SYSTEM

As a typical case, in Fig. 4, the variation of image quality measured by peak signal-noise ratio (PSNR) , the quantization parameter (QP) and the bit rate of one of the eight users under above mentioned schemes A and B. Case A and Case B are given for comparison. From the simulation results, it is clear that the presented equal distortion criterion has resulted in approximate the same image quality among different users at any time instant. At the same time, it is shown that the variation of image quality from time to time is considerably decreased. The overall subjective image quality has been greatly improved.



(a)



(b)

Figure 4. SOME SIMULATION RESULT

SNR is measured in dB and rate is measured by hundreds of bits/sec: (a) and (b) are of one user under schemes A and B, respectively.

IV. SUMMARY AND CONCLUSIONS

In this paper, a novel *equal distortion* scheme is presented to control bit rate among different users in multi-user VBR communication system. By adopting this scheme, the variation of video quality for each user has been greatly decreased compared to the *equal bandwidth* allocation scheme. The overall service quality has been considerably improved. By introducing some reasonable approximation in both source model and deduction process, a rather simple and easy application form of this scheme is obtained.

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