DYNAMIC PROFILING ALGORITHMS FOR LOW BIT RATE VIDEO APPLICATIONS

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ABSTRACT

In this paper we propose three algorithms for low bit-rate (LBR) video transmission, namely Simple Dynamic Profiling (Simple DP), Minimum Dynamic Profiling (Minimum DP) and Mean Dynamic Profiling (Mean DP). These techniques can be used in conjunction with other low bit rate techniques. Many of the techniques available for low bit rate video applications will either require lot of hardware resources or take advantage of the powerful computer platform that is used for their software implementation. On the other hand, the proposed algorithms are devised targeting hardware implementation for systems with limited hardware resources. When compared to coarse quantization technique, the new techniques not only achieve better compression ratio (twice that of the coarse quantization), but also result in better PSNR results (27 db for the coarse quantization versus 33 to 36 db for the new techniques).

1. INTRODUCTION

Coding for low bit rate video applications has gained a special interest among the video coding community especially with the emergence of many applications such as videoconferencing, video telephony, surveillance, and monitoring [1-3]. In each case, video and audio information are transmitted over telecommunications links, including networks, telephone lines, ISDN and radio. The ITU based H.263 standard was proposed for low bit rate video applications with bit rates below 64Kbits [3-4].

Many of the techniques proposed for LBR either require the use of lot of hardware resources or belong to a set of software based solutions targeting platforms with powerful computing capabilities and resources. Mobile and portable applications are characterized by scarce computing resources: energy, CPU power and memory resources. Integrating video applications into such devices will require that these applications are tailored to such limited environments.

In this work, three algorithms (SimpleDP, MinimumDP, and MeanDP) are proposed as hardware solutions for LBR applications targeting mobile and portable devices. These algorithms attempt to group similar 8×8 DCT coefficient blocks across a frame into different sets according to a predetermined threshold which could be selected for example depending on the communication link congestion. All DCT blocks belonging to a set are replaced by their set number, and instead of transmitting an 8×8 block we transmit only a reference number. The proposed algorithms are characterized by their efficient compression ratio, good PSNR results, and feasible hardware implementation.

This paper is organized as follows: in section 2, previous work in LBR is addressed. Section 3 introduces the proposed algorithms, and comparison and simulation results are presented in section 4. Concluding remarks are presented in section 5.

2. PREVIOUS WORK

Some of the work addressing LBR coding can be found in [5-12]. Many of these techniques rely on the fact that the software implementation is targeting video transmission over limited communication bandwidth channels between computer platforms with lot of computing resources. This limited communication bandwidth necessitates the utilization of very high compression schemes while maintaining acceptable video signal qualities. These sophisticated compression schemes are implemented on such powerful communication nodes utilizing their rich set of resources, namely, processing power and memory.

For example, in [5] downsampling of the sequence frames is employed before coding, and interpolation is used to obtain the original resolution at the receiver. In this work an optimal frame work for designing the decimation and interpolation filters is presented. In LBR applications, especially very LBR applications, frame skipping cannot be avoided leading to significant reduction in visual quality and interruption of frame sequence smoothness of the reconstructed video. In [6], an optimal algorithm using dynamic programming at the encoder is used to minimize the number of skipped frames in a scene cut where sequence smoothness is interrupted. In addition, [7] uses adaptive thresholding and bit allocation mechanisms in order to reduce the occurrence of frame skipping without sacrificing the overall PSNR of the reconstructed video. In this work, P-frames close to the I-frame are assigned higher encoding priority and thus more bits than P-frames close to the end of the segment. In addition, the target buffer level is updated adaptively according to the frame type being coded.

In [8-9] LBR techniques are employed in video transcoding. Transcoding is a process of converting a previously compressed video stream into a lower bit-rate stream. When frames are dropped in transcoding, the quantized DCT coefficients of the prediction error need to be recomputed. In [9], a frame-rate control scheme is proposed which can dynamically adjust the number of skipped frames according to the incoming motion vectors and the re-encoding error due to transcoding such that the decoded sequence can have smooth motion as well as better transcoded pictures.

Due to their frequency selectivity and orientation specificity [10], wavelets are used in image processing to form a multiresolution representation of images. In [10] it is stated that the subbands produced by the wavelet subband decomposition can be encoded using vector quantization for the development of LBR compression schemes. Another major technique for LBR is channel buffer utilization schemes using coarse quantization [11-12]. The quantization step is determined by iteratively comparing output bit rate with a target bit rate which is based on the desirable bit rate, frame code mode, frame complexity and scene changes. In [12], an adaptive control scheme is proposed based on buffer fullness, quantization, and buffer utilization for LBR communication lines.

Except for the quantization based techniques, all techniques will require the use of lot of hardware resources to achieve the LBR rates.

3. DYNAMIC PROFILING ALGORITHMS

When targeting video transmission to/from mobile and battery operated devices, we have limitations in both communication bandwidth and computational power. In our work, we are targeting low bit rate video coding for platforms with limited resources. As such, one of the main criteria will be low design complexity caught by simple processing elements and low memory requirement.

In these algorithms, similar DCT blocks within a frame (residual frames or intra-frames) are grouped into different sets. A set is represented by an 8×8 DCT Coefficients block, and the similarity testing is done using an error function such as sum of absolute difference (SAD) between the set representatives and the DCT blocks within a frame. As a result, one can replace the transmission of a block by the transmission of the set into which B belongs, as well as the transmission of all sets created for a frame. Figure 1 shows the overall function of the dynamic profiling technique. Given a frame, the dynamic profiling technique uses the DCT output to generate two entities: a DCT table holding all sets created, and a reference list that represents all DCT blocks of the frame with set numbers.

Two main issues need to be addressed for the Dynamic Profiling algorithms which are: set representative selection and selection of the set for a DCT block. Based on these two issues we can have three algorithms (Simple, Minimum, and Mean Dynamic Profiling algorithms), and they are presented in the following subsections.

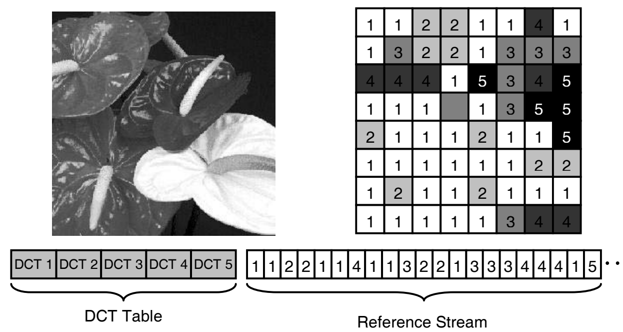

Fig. 1: Dynamic Profiling Technique

3.1. Simple DP

For the Simple DP algorithm, a set is represented by the first DCT block to be added to the set when it is first created. In addition, a DCT block is added to the first set to pass the threshold test. Figure 2 shows the Simple DP algorithm. The first 5 lines are used for initialization, and the first DCT block of a frame is used to create the first set, and this DCT block is used as a representative for the newly created set. The loop (lines 6-26) is used to go through all DCT blocks of a frame. The inner loop (lines 11-20) is used to check if the current DCT can be added to the current list of sets through the threshold test, which is an error SAD function between the current DCT and a set-representative. If the threshold test is passed for a set, we exit the loop. If the threshold test is never passed for any of the available sets, then the current DCT is used to create a new set (lines 21-25). The outputs of this algorithm will be the Set table (Coef_Table) and the reference list (Stream).

3.2. Minimum DP

This algorithm is similar to the Simple DP except that a DCT is added to a set that results in the minimum SAD error. Figure 3 shows the algorithm for the Minimum DP.

The minimum SAD is tracked in lines 13-16, and the inner loop is repeated till all sets are tested. If a minimum exists at the end of the inner loop, then the DCT is added to the set with the corresponding minimum error. In no set passes the threshold test, then the current DCT is used to create a new set (lines 21-26). Similar to the Simple DP algorithm, the outputs of this algorithm are Coef_Table and Stream.

```
01  X=first 8×8 block.
02  Coef=DCT(X);
03  Coef_Table(1)=Coef;
04  Max=1;
05  CAT(Stream,Max);
06  for each 8×8 block X in the current frame
07      Coef=DCT(X)
08      New_entry=1;
09      Stop=0;
10      index_table=1;
11      while (Stop==0)&(index_table≤Max) do
12          load_coef=Coef_Table(index_table);
13          temp=SAD(load_coef - Coef);
14          if (temp<Threshold)
15              new_entry=0;
16              CAT(Stream,index_table);
17              Stop=1;
18          end_if(temp<Threshold)
19          index_table++;
20      end_while
21      if (new_entry=1)
22          Max++;
23          Coef_Table(Max)=Coef;
24          CAT(Stream,Max);
25      end_if (new_set=1)
26  end_for each 8×8 block X
```

Fig. 2: Simple Dynamic Profiling Algorithm

5.2. Minimum DP

The Mean DP uses the output of the Minimum DP algorithm. For each set, all DCT members are used to calculate the mean, and this mean is used then to represent the set. The drawback of this algorithm is that the results are created using two passes, which may not be suitable for real-time applications.

4. SIMULATION RESULTS

All three algorithms take the 8×8 quantized DCT coefficient blocks as one input entity and upon processing of a whole frame, they deliver two outputs: a DCT table and a reference stream, Fig. 1. While DCT results are delivered to units implementing these algorithms at fixed rates, the Dynamic Profiling units carry out time consuming operations and the output rate will not be fixed. In order remedy this problem, one can employ buffering and pipelining techniques in order to achieve fixed rates and reduce latencies.

In testing all these algorithms we have used compression for still frames such as Flower, and the resulting image size and PSNR values are used for comparison with the coarse quantization technique because such technique is feasible for hardware implementation. All algorithms were implemented using MATLAB. We have simulated the algorithms performance on the Flower frame where we have varied the threshold from 0 to 200 for all three Dynamic Profiling algorithms. In addition the quantization parameter (QP) is controlled to generate coarser versions of the Flower Frame.

```
01  X=first 8×8 block.
02  Coef=DCT(X);
03  Coef_Table(1)=Coef;
04  Max=1;
05  CAT(Stream,Max);
06  for each 8×8 block X in the current frame
07      Coef=DCT(X)
08      New_entry=1;
09      for index_table=1 to Max
10          load_coef=Coef_Table(index_table);
11          temp=SAD(load_coef - Coef);
12          if (temp<Threshold)
13              if(temp<min)
14                  min=temp;
15                  min_index=index_table;
16              end_if(temp<min)
17              new_entry=0;
18          end_if(temp<Threshold)
19      end_for index_table=1 to Max
20      if (new_entry=1)
21          Max++;
22          Coef_Table(Max)=Coef;
23          CAT(Stream,Max);
24      else
25          CAT(Stream,min_index);
26      end_if (new_entry=1)
27  end_for each 8×8 block X
```

Fig. 3: Minimum Dynamic Profiling Algorithm

Figure 4 shows the effect of threshold on the number of sets created for the Simple Dynamic Profiling algorithms; as the threshold gets larger, the number of sets created gets smaller, and more error is generated. This behavior leads to smaller frame sizes and lower PSNR values. Figure 5 shows the effect of frame size on the PSNR of all Dynamic profiling algorithms compared to the coarse quantization technique. The proposed algorithm not only outperforms the coarse quantization technique in terms of PSNR results, but they also can achieve lower frame sizes with good PSNR values. For subjective analysis, Fig. 6 compares compression using the coarse quantization technique to the compression using the three DP algorithms. The coarse quantized frame suffers from excessive existence of blocking artifacts and blurring due to the elimination of the AC coefficients.

The main operations involved in these algorithms are SAD calculations, Memory Read/Write, Increment and comparison operations. The memory is used to hold the DCT representatives of the created sets for one frame. In the worst case where the threshold value is zero, every incoming DCT block of the frame represents a unique set, and the memory needs to store all DCT blocks of this frame. Hence a memory block of the size of one frame is required. Since the frame size is small in LBR applications, memory design of such sizes is relatively feasible.

5. CONCLUSIONS

In this paper we have presented three algorithms, Simple DP, Minimum DP, and Mean DP algorithms for low bit rate video coding. Simulation results show that these LBR techniques outperform coarse quantization. The proposed algorithms, unlike many of available techniques for low bit rate, are proposed targeting platforms with reduced computation power and reduced resources.

6. ACKNOWELEDMENT

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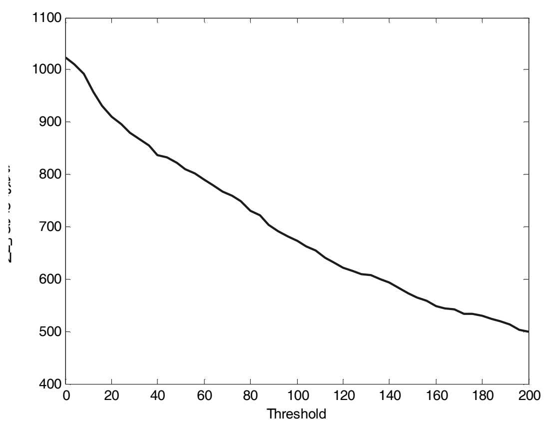

Fig. 4: Threshold effect on the number of sets created for Simple DP Algorithm

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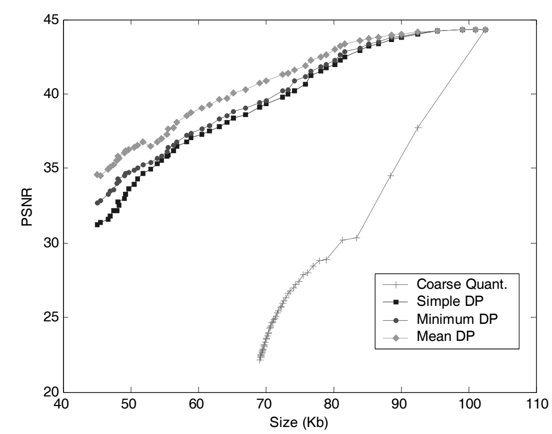
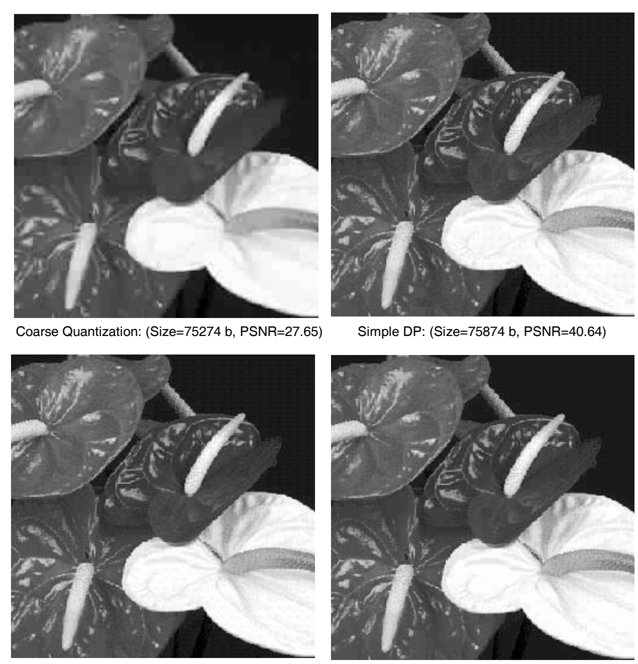


Fig. 5: Coarse Quantization compared to the Dynamic Profiling Algorithms



Coarse Quantization: (Size=75274 b, PSNR=27.65) Simple DP: (Size=75874 b, PSNR=40.64)

Minimum DP: (Size=75874 b, PSNR=41.15) Mean DP: (Size=75874 b, PSNR=41.86)

Fig. 6: Subjective comparison of Coarse Quantization to Dynamic Profiling Algorithms.