REVIEW OF PRACTICAL MPEG POST-PROCESSING METHODS FOR THE CONSUMER VIDEO PROCESSING CHAIN

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ABSTRACT

The consumer video comes in a range of visual quality from HD to very poor quality SD video. MPEG compression noise is very serious problem for low quality and medium quality content. In this paper we will review the MPEG post processing techniques and discuss the practical implementation problems in the context of HD up-converted video.

1. INTRODUCTION

The consumer video processing chain is mainly classified into three categories, namely (analog and digital) noise reduction algorithms, format conversion/conditioning algorithms and sharpness/color/contrast enhancement algorithms. The noise reduction algorithms try to reduce digital noise introduced because of video compression (blocking and ringing noise) and also analog noise which is mainly introduced because of the analog transmission/capture.

In this paper we mainly want to review the MPEG post processing techniques and discuss the practical problems faced in during the implementation. The compression noise introduced by MPEG2 video standard are mainly categorized as – Blocking artifact, Ringing artifact and Mosquito Noise.

Blocking artifacts are introduced because of discontinuities at the block boundaries in the reconstructed frame. The discontinuities are characterized by tiling effect of 8x8 blocks in case of MPEG2 video coding standard and 4x4 blocks in the H.264 standard. In H.264 an in-loop deblocking filter [2] is included as the part of the standard to reduce the blocking artifact; hence, it is a part of H.264 encoder. The blocking artifacts are mainly visible in smooth and slowly changing regions compared to the textured region.

Ringing artifacts are introduced by coarse quantization of high frequency components. After inverse transform the blocks in which high frequencies are lost form ringing artifacts – around the strong edges. Severity of the ringing artifact is reduced in the case of H.264 video coding because of the smaller coding blocks.

The mosquito noise is the temporal effect caused also by the quantization of high frequency values. The object boundaries may not very well reproduced after the block-based motion compensation hence these introduce motion compensation errors which will introduce temporal business around the moving edges.

In this paper we will discuss the most popular methods for MPEG post-processing and the specific challenges that arise when the post-processed MPEG video is up-converted to HD format. Special attention will be given to increased visibility of artifacts and post-processing side effects.

The paper is organized as follows. In Section-2 we will discuss the MPEG noise reduction algorithms and related detection method. In Section-3 we discuss soft thresholds which are important in practical implementations for the HD framework. In Section-4 we discuss video chain tuning and finally conclusions in Section-5.
2. MPEG NOISE REDUCTION METHODS

2.1. Blocking noise reduction
Blocking artifact reduction methods are mainly classified into spatial domain methods and frequency domain methods. Usually they assume that the grid information is available. The spatial domain methods are attractive when the decoder is not locally available. The spatial methods try to redistribute the energy by re-aligning the pixels on either side of the artifacts. A low-pass filter is also applied selectively such that edges are preserved and visible effects of pixel re-alignment are not visible. The frequency domain methods work either in DCT domain [3] or in wavelet domain. These methods mainly use frequency shrinkage technique to reduce the high frequency of the discontinuities at the block boundaries. All the above methods need grid information to correctly apply the filter. Iterative methods [4, 5, 6] (e.g. POCS and regularization) can work in either the frequency domain or in the spatial domain but are less attractive for real-time implementation because of the higher complexity.

2.1.1 Deblocking of interlaced content
In the case of interlaced content (which needs to be de-interlaced and scaled), if the deblocking filter is applied separately to each field, then a banding effect (flat stripe 4-pixels wide around the artifact) may be seen because of mismatches at block boundaries. The banding effect is more pronounced in the smooth regions. In the case of spatial filter with pixel re-alignment filter, banding can be avoided by adjusting the weights of the realignment filter such that there is a smooth transition across the block boundaries.

\[ \text{Figure-1 Blocking artifact in interlaced content} \]

2.1.2 Deblocking of chroma components
Deblocking of the chroma components is not very critical compared to luma components. At very low bitrates deblocking of chroma components is required to avoid visible artifacts in HD displays.

2.2. Ringing and mosquito noise reduction algorithm
Like blockiness reduction, ringing noise reduction (de-ringing) can be done in the spatial domain or in the frequency domain. In the spatial domain, de-ringing is an edge-driven process made possible by filtering in the direction normal to strong edges (with or without prior detection of ringing pixels or areas prone to the artifact). Non-linear filtering methods that use pixels similar to the one being filtered are also used in the spatial domain (e.g. central median, epsilon filters, etc.). More computationally intensive methods based on MAPS and POCS have also been published. In the frequency domain, wavelet shrinkage methods have been published [1], as well as other methods for joint deblocking-deringing. Mosquito noise reduction is usually done by outlier filters in a similar manner to deringing, but it includes temporal filtering as well. Mosquito noise reduction algorithms need good motion estimation information to do the filtering in temporal direction. Poor de-ringing and mosquito noise reduction may result in visible flicker effect or excessive blur.

De-ringing, mosquito noise and de-blocking filters must have control parameters to adjust their effect on the video chain that may include de-interlacing and scaling (plus sharpness/contrast/color enhancement).

2.3. MPEG grid detection
The MPEG grid information needs to be determined to apply the deblocking filter if the decoder is not locally present. The grid detection algorithms try to find the local maxima in the images to determine regular pattern of thin edges at constant row/column intervals. The broadcasters do the down-scaling in horizontal direction (usually by a factor of 2/3 or 3/4) to reduce the bandwidth, especially important for HD content. Hence there is need to handle irregular grid sizes.

2.4. Ringing and mosquito noise detection
Ringing noise when present resides only in the affected DCT block. Once the MPEG grid detection algorithm detects the grids, if a strong edge is detected within the DCT block then ring noise can be seen in that block. The mosquito noise will be present in the DCT blocks which have motion pixels.

2.5. Single vs. multiple denoising algorithms
Specialized algorithms can exhibit higher performance for specific types of digital (e.g. deblocking) or analog (e.g. Gaussian) noise. However, in consumer video applications the sum of the parts (in performance and cost) is what defines the video processing chain. Algorithms that combine several types of noise as their target are more attractive provided that they represent a viable cost-performance alternative.

A relatively new class of algorithms is aimed at reducing noise from digital and analog origin. These filters are mainly claimed in some commercial products. Although there is no generic analog-digital noise model, non-linear, region-adaptive low-pass filters may exhibit broad denoising behavior which is exploited by these methods.

3. SOFT THRESHOLDS

If the decoded video is sent through an analog input then noise becomes a problem. It is mainly characterized as Gaussian noise. Sometimes this acts in the favor of deblocking algorithm due to the low-pass effect on the blocking artifacts. In the hardware implementation because of the analog noise one has to be careful about the application of hard thresholds. If there is noise, when the pixel value is at the threshold then the image can flicker because of the wrong/different decisions by the adjacent pixels, which might cause serious problems later in the video chain. To deal with this problem, a possible technique is a soft rollover of the threshold which can be achieved by piece-wise approximation of the threshold curve as shown in Figure-2. Methods based on fuzzy logic or inexact reasoning are also possible.

4. VIDEO CHAIN TUNING

The noise reduction algorithms need to be tuned along with conditioning and enhancement algorithms. The noise reduction algorithms usually cause blurring which after scaling of the video will be a severe problem. Hence, a sharpness enhancement algorithm needs to be introduced to reduce the blurring effect. One also has to be careful of over enhancement or noise enhancement if the noise is not cleaned initially in the video chain. The scaled image will boost any artifact introduced by the algorithm and hence make the matters worse.

In the tuning processing conducted it is found that noise reduction algorithms at the beginning of the video chain give better results. The severity of the MEG noise is content dependent. But the following observations have been made during the tuning process. The blocking noise at very low bitrates masks the ringing noise. Hence, for the standard definition video at bitrates less than 2Mbps, the blocking noise reduction gives the best quality improvement. The ringing noise is more pronounced for standard definition content between 2 and 5Mbps. The deblocking algorithms strength should be reduced for these bitrates as it might blur the content below the acceptable quality. The mosquito noise is visible when there is slowly moving objects. An option to the rule of compression values would be to use blockiness and ringing metrics to detect the dominant artifact.
5. CONCLUSION

Although MPEG post-processing can be considered a mature field, application of the best known techniques in the context of HD consumer video poses new challenges. The up-converted SD video is currently viewed in large screens of very high quality (e.g. plasma, LCD). Good MPEG post-processing must perform well not in isolation but along with all other components of the video processing chain.

In this paper we have addressed specific issues such as increased visibility of artifacts and side effects of post-processing. The main issues are:

1. Finding the best performance regions for post-processing in the HD video processing chain. Given the risk of lowering quality and the broad range of compression, we find it preferable to focus processing on the dominant artifact, and ignore low level ones.
2. Side effects of post-processing which may not be visible in SD may require modified or tuned-up processing to avoid negative impact. Processing of interlaced video requires special attention to avoid banding effects and flicker.
3. Soft thresholds appear to be necessary to deal with noise which may trigger post-processing irregularly in spatial/temporal dimension thus causing flicker.
4. Given the complexity and cost of the HD video processing chain, algorithms that perform multiple functions appear to be preferred in order to reduce computational load and meet the increased bandwidth requirements of HD.

6. REFERENCES