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Abstract

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I. INTRODUCTION

MPEG-2 is the primary format for broadcast video, where the data rate for high-definition video is approximately 20Mbps. The latest video coding standard, referred to as H.264/AVC, is able to achieve the same quality as MPEG-2 with about half the data rate. Since the H.264/AVC format has been adopted into storage format standards, such as Blu-ray Disc, we expect H.264/AVC decoders to appear in consumer HDD systems soon. Certainly, as more high-definition content becomes available, long recording mode will be a key selling point for future HDD recorders.

To satisfy this need, we are developing novel techniques that convert the MPEG-2 broadcast video to the more compact H.264/AVC format with low complexity. Complexity is kept low by reusing information contained within the MPEG-2 broadcast video. At the same time high quality is maintained. The diagram of the proposed system is shown in Figure 1. Since MPEG-2 decoder is present in existing systems, the challenge becomes how to integrate the simplified H.264/AVC encoding part of the MPEG-2 to H.264/AVC transcoder into the system.

The remainder of this paper is organized as follows. First, we describe proposed low-complexity transcoding techniques. Then, we discuss issues related to the HDD recording system design. Next, we provide experimental results demonstrating the advantage of using the H.264/AVC format for storage. Finally, concluding remarks are provided.

II. TRANSCODING TECHNIQUES

We have developed transcoding techniques for intra and inter pictures. These techniques are described further below.

A. Intra transcoding techniques

We developed a transform-domain MPEG-2 to H.264/AVC intra video transcoder architecture. Input DCT coefficients are first converted to H.264/AVC transform (HT) coefficients in the transform-domain. A fast rate-distortion optimized macroblock mode decision based on a simple cost function

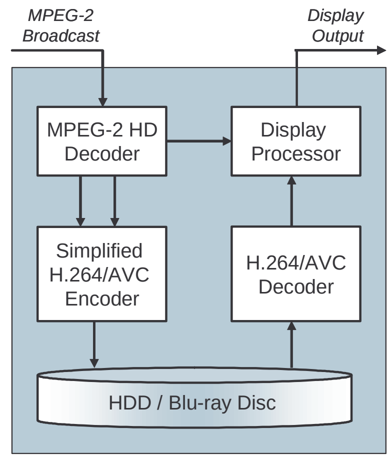

Figure 1. Storage system using MPEG-2 to H.264/AVC.

calculated in the HT-domain is then performed. Finally, the HT coefficients are coded using the selected modes to generate the output H.264 bitstream. This transcoder architecture reduces the complexity requirement about 50%, while maintaining virtually the same coding efficiency. For more information, please refer to [1].

B. Inter transcoding techniques

The key to reduce the complexity for inter transcoding is the motion re-estimation and mode decision, which typically accounts for more than 80% of a full H.264/AVC encoder. In this paper, we extend the efficient transform-domain mode decision algorithm proposed in [1][2] for inter mode decision.

We first rank all candidate macroblock modes based on the SATD costs. For a block, the SATD cost is defined as:

$$cost_1(m) = \left\| E(m) \otimes W_1 \right\|_1 + \lambda_{\mathrm{MODE}} * 4 * (1 - \delta(m = m^*)) \quad (1)$$

where $E(m)$ is the HT coefficients of the prediction residual signal for a mode m, λ_{MODE} is the mode Lagrange multiplier, and m^* is the most probable mode for the block. The $\otimes$ operator represents a scalar multiplication or element-wise multiplication of two matrices. Note that the transform here is the HT, not the Hadamard transform as used in JM software.

Next, we select only the few (k=3) best modes with the smallest SATD costs for the evaluation of Lagrange costs:

$$cost_2(m) = \left\| (E(m) - \tilde{E}(m) \otimes W_2) \otimes W_1 \right\|_2^2 + \lambda_{MODE} * R(m) \quad (2)$$

where $\tilde{E}(m)$ are the HT coefficients of the reconstructed residual, $R(m)$ is the rate of the block using mode m, and W_1

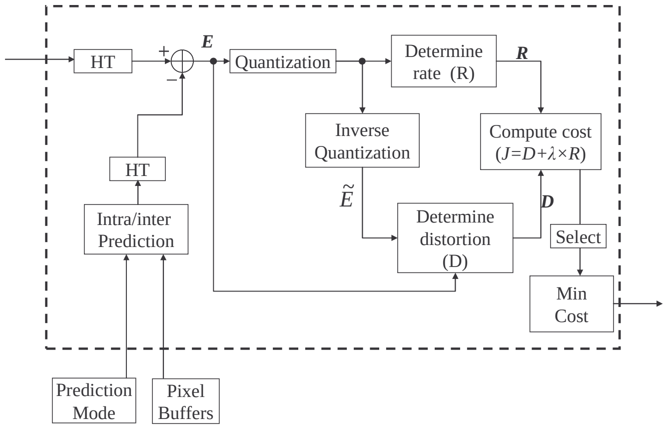

Figure 2. Lagrange cost calculation in transform domain.

and W_2 are scaling matrices to compensate the different norms of HT, inverse HT and H.264 quantization design [1]. The calculation of $cost_2$ is performed efficiently in the transform domain (see Figure 2). Since $cost_1$ is much simpler to compute than $cost_2$, the complexity is significantly reduced.

Efficient motion re-estimation algorithm would rely on intelligently reusing the motion information available in the incoming MPEG-2 video stream. Considering the large amount of coding modes available in H.264/AVC, it would be desirable to further reduce the complexity by optimizing motion estimation and mode decision jointly [3][4].

III. SYSTEM DESIGN

As mentioned earlier, existing HDD recorders have MPEG-2 decoders and they are expected to have integrated H.264/AVC decoder in the near future. Therefore, we only need to integrate the transcoder into the recorders to achieve efficient storage using H.264/AVC. To achieve a low-complexity transcoder, macroblock information, including motion, mode and quantization parameter, need be provided to it. Intuitively, the most cost effective solution would be to output the macroblock information directly from the MPEG-2 decoder. Then, the only additional component is the transcoder itself.

However, it may not always be possible to output the macroblock information from MPEG-2 decoder. For instance, there may be systems using off-the-shelf MPEG-2 decoders that do not have macroblock information output. In this case, we include an MPEG-2 video parser into the system to parse the macroblock information and provide this information to the transcoder. Although slightly less cost-effective in terms of system design, this solution is independent of the MPEG-2 decoder selection and might end up less expensive in terms of overall cost.

IV. EXPERIMENTAL RESULTS

To demonstrate the storage benefits using the proposed MPEG-2 to H.264/AVC transcoding techniques, we performed the following simulations. We use five 1280x720x60p HDTV sequences: BigShips, Crew, Harbour, Jets, and Night. We encode them first using MPEG-2 at 15Mbps. Then, we transcode them to H.264/AVC format using our low-complexity transcoder to 7Mbps. The resulting quality in terms of PSNR is shown in Figure 3. For comparison, we also include the case where the HDTV sequences are encoded to a rate of 7Mbps using MPEG-2. Compared to the input MPEG-2 stream at 15Mbps, the average PSNR loss of transcoding to H.264/AVC at 7Mbps is around 1dB, while the loss for MPEG-2 at 7Mbps is close to 3.5dB.

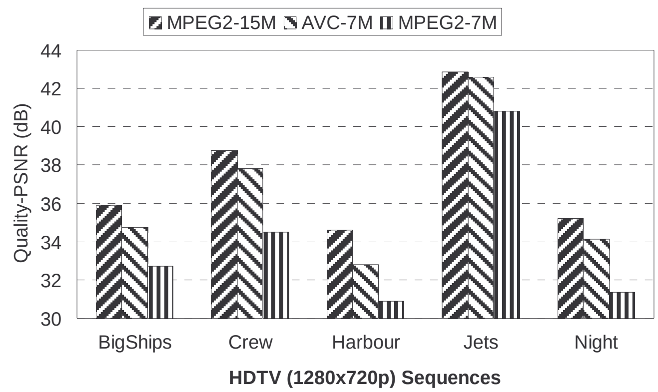

Figure 3. Performance of MPEG-2 to H.264/AVC transcoding measured in PSNR for three cases: MPEG-2 encoded at 15Mbps (MPEG2-15M), transcoded AVC at 7Mbps (AVC-7M), and MPEG-2 encoded at 7Mbps (MPEG2-7M).

V. CONCLUDING REMARKS

We demonstrated that MPEG-2 to H.264/AVC transcoding has great potential to provide efficient storage and long recording time in storage applications. We discussed low-complexity transcoding techniques, which are the key to the success of such recording system. We also discussed system design issues on how to integrate the low-complexity transcoder into a recording system.

REFERENCES

[1] Y. Su, J. Xin, A. Vetro and H. Sun, "Efficient MPEG-2 to H.264/AVC Intra Transcoding in Transform-domain," *Proc. IEEE Int'l Symp. Circuits Syst.*, Kobe, Japan, May 2005.

[2] J. Xin, A. Vetro, and H. Sun, "Efficient Macroblock Coding Mode Decision for H.264/AVC Video Coding," *Proc. Picture Coding Symposium*, Davis, CA, Dec 2004.

[3] Z. Zhou, S. Sun, S. Lei and M.T. Sun, "Motion information and coding mode reuse for MPEG-2 to H.264 transcoding," *Proc. IEEE Int'l Symp. Circuits Syst.*, Kobe Japan, May 2005.

[4] X. Lu, A. Tourapis, P. Yin and J. Boyce, "Fast mode decision and motion estimation for H.264 with a focus on MPEG-2/H.264 transcoding," *Proc. IEEE Int'l Symp. Circuits Syst.*, Kobe, Japan, May 2005.