An MPEG Decoder with Embedded Compression for Memory Reduction

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ABSTRACT

We present an MPEG decoder with reduced system costs by employing embedded compression of the reference frames which are used for motion-compensated (MC) decoding. The compression features simple recovery of (MC) block data, while preventing visible artifacts. The compression was optimized for low costs, enabling real application in a commercial MPEG IC.

INTRODUCTION

The MPEG video compression standard [1] is being applied in numerous applications, such as video communication in the multimedia PC, Digital Video Broadcasting (DVB) and more recently, storage of video sequences on the Digital Versatile Disk (DVD). The evolution of the aforementioned applications is clearly towards large-scale usage in the consumer electronics area. This market is characterized by a heavy pressure on low system costs and a continuous price erosion. In this paper, we have studied a new technical solution to realize lower system costs for an MPEG decoder, without sacrificing the resulting picture quality after decoding, by compressing the reference video frames that are kept in memory during the decoding process.

System costs in the MPEG decoder are dominated by the bi-directional motion compensation unit, which employs two frame memories to store the previous and next reference frames (I and P pictures). The memory cost of two 4:2:0 sampled images as used in MPEG main level is 10 Mbits. The required bandwidth to offer two full-colour reference frames simultaneously is 50-60 MB/s, while the required decoding speed for real-time operation is 16–18 MHz.

SYSTEM REQUIREMENTS

For reduced system costs, the reference frames are typically stored in a Synchronous DRAM (SDRAM) of e.g. 16 Mbits capacity (see Fig. 1). This memory serves

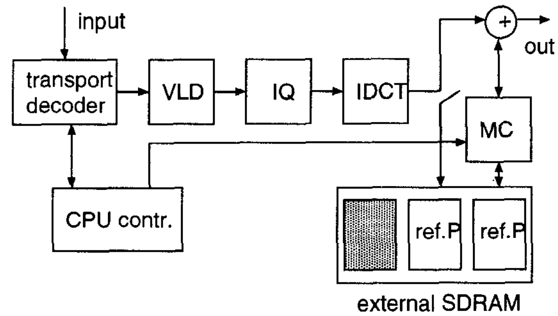

Figure 1: MPEG decoder architecture diagram.

also as a background memory for a CPU which controls the MPEG decoder and generates additional On-Screen-Display menus for user control. (indicated by the hatched area in Fig. 1). The costs of the memory usage for motion compensation is reduced by *recompressing* the reference frames prior to memory storage, in order to save memory capacity for other purposes (CPU etc.).

Besides high picture quality and low complexity, two important system constraints for the *embedded compression* of reference frames in MPEG have to be satisfied.

Accessibility. The motion compensation using a motion vector for each macroblock (MB), requires that MB-data should be retrieved from the background memory on "arbitrary" positions, which mostly do not coincide with the static block grid (see Fig. 2). The embedded compression should allow easy extraction of the reference data.

Stable quantization after multiple encodings. The recursivity in MPEG, where P-pictures form the input for the subsequent iteration of P-picture reconstruction, requires that accurate quantization is performed, when embedded compression is performed in between. Otherwise, the decoder would drift away from the local reconstruction loop as applied in the encoder, leading to e.g. colour distortion.

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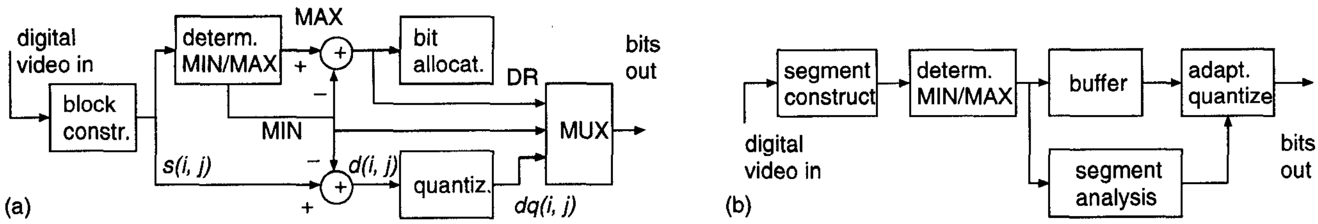

Figure 3: (a) Block diagram of BPC system encoder and (b) feedforward coding system based on BPC.

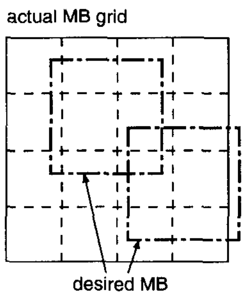

Figure 2: Locations of required motion-compensated blocks on actual macroblock (MB) grid.

EMBEDDED COMPRESSION SYSTEM

A high picture quality and low complexity was obtained by using Block Predictive Coding (BPC) on a local basis (small blocks). The first step of the BPC is partitioning the image into subblocks of 4×4 pixels. Subsequently, the maximum (MAX) and minimum (MIN) pixel values of each block are determined. The difference between the MAX and MIN value in a block is called Dynamic Range (DR). For low cost, the MIN sample value is transmitted as a global prediction for all other samples inside the block [3]. After subtracting this minimum value of the actual sample value $s(i, j)$, all difference values $d(i, j)$ of a block are quantized according to the dynamic range, resulting in $dq(i, j)$.

Because of the accessibility constraint, we use a compression system that generates fixed-length data packets for a group of MPEG macroblocks (see Fig. 3(b)). Each group is compressed independently and has a size of 9 MBs. This so-called *feedforward coding* technique was adopted from digital video recording [2]. The video data is first analysed with a set of various quantization strategies. The strategy chosen after analysis is the finest quantization that yields the desired number of bits reserved for a group of 9 MBs.

RESULTS

We have integrated the embedded compression in the MPEG codec designed by the MPEG Software Simulation Group. In order to quantify the loss in image quality from embedded compression, a set of experiments has been conducted. First, the original video image has been compared with the reconstructed MPEG image with and without embedded compression. A set of (embedded) compression factors ranging between 2–2.5 has been used. In Table 1, the original is the well-known MOBI sequence, which has been MPEG compressed with typical parameter settings at 9 Mbit/s.

The quality of the reconstructed MPEG sequence (SNR=26.9 dB) is hardly influenced by the embedded compression which operates at a much higher quality (SNR$\geq$38 dB). The negligible loss of embedded compression is substantiated by the measurements in Table 1 (see first row). For lower bit rates (e.g. 4 Mbit/s), the SNR between the original and the reconstructed MPEG image decreases, such that the losses introduced by embedded compression are even vanishing. Interesting details were found for improving the acessibility of Macroblocks and the tuning of the quantization when very long MPEG GOPs (group of pictures) are used. Computer simulations showed that a very high quality was possible, giving a negligible loss for short GOPs and a few dB SNR loss for very long GOPs. These promising results have led to the decision to include our proposal into a commercial IC design.

Reference	CF 1	CF 2	CF 2.3	CF 2.5
Orig. vs. MPG (Emb.)	26.9	26.7	26.7	26.5
MPG vs. MPG Emb.		45.0	41.4	38.7

Table 1: SNR of the Y signal for different embedded compression factors (CF).

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