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Title: **FF/FR Using Frequency Scalable Layered Coding**

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Purpose: Information

Abstract:

This document reports on preliminary results for Fast Forward/Fast Reverse (FF/FR) trick modes obtained using a Frequency Scalability layered coding scheme. Results indicate that, under the assumption of particular bandwidth constraints associated with FF/FR trick modes, Frequency Scalability may prove to be a very suitable method to achieve FF/FR features.

Introduction

The aim of our experiments was to investigate the suitability of Frequency Scalability layered coding to provide efficient FF/FR functionality. The reason we advocate Frequency Scalability, because FF/FR functionality is readily provided within the layering scheme without any additional syntax changes. Providing limited SNR Scalability and Resolution Scalability features (but not the full capability offered by the scalability extension) would be an advantage that is a by-product of providing good FF/FR capability in this manner.

A. Frequency Scalability Layered Coding

Very similar to Data Partitioning method, Frequency Scalability achieves layered coding in the DCT coefficient domain. Lower frequency DCT coefficients are transmitted in a lower layer and higher DCT coefficients in one or more higher layers. Since each layer will only contain a defined subset of the 8x8 DCT coefficients (i.e. 2x2, 4x4, 8x8) it is to the choice of the receiver to decide how to decode and display the lowest layer. For example in a 3 layer scheme, the lowest layer may contain the lowest 2x2 DCT coefficients. A receiver who only decodes the lowest layer for FF/FR purposes may decode the video using an inverse 8x8 DCT (with the remaining 60 DCT coefficients padded with zeros) thus displaying the FF/FR video at full spatial resolution (SNR Scalability). Alternatively the receiver may decide to decode the

lowest layer using an inverse 2x2 DCT and display the FF/FR video at one quarter of the original spatial resolution in each dimension (Resolution Scalability).

The bit rate of each layer can be controlled independently in a Frequency Scalability coding scheme. Using a Frequency Scalability "Pyramid" a maximum flexibility for allocating DCT coefficients into particular layers can be achieved. The lowest 2x2 layer may only contain the first DCT coefficient (DC) for efficient FF/FR rate control purposes if desired.

B. Desirable Bandwidth Constraints

Based on recommendations discussed in the MPEG FF/FR Mode AdHoc Group (for a simple VCR model) we targeted varying bit rates for different FF/FR speed-up factors. The FF/FR target bit rate (TBR) was calculated according to the formula

TBR = (1/2F) * encoded_bitrate

for a speed-up factor of F.

Experiments

For experimental purposes a 3 layer Frequency Scalable coding scheme was implemented to achieve both FF/FR trick mode functionality as wepll as Resolution Scalability. For FF/FR purposes only the lowest 2x2 layer was decoded (only I-frames for a speed-up factor of 12 and I-frames and P-frames for a speed-up factor of 3). No rate control was implemented to control the bit rate of the lower layers.

Bit rate for full spatial and temporal resolution:	4 Mbps
Number of frames:	58
N:	3
M:	12
Prediction/Coding	Frame Prediction/Coding only
3 Layers:	2x2, 4x4, 8x8 coefficients
Encoding loops:	1 (only one frame store at encoder)
Scanning:	Pyramid
TBR for speed-up factor F = 3:	0.667 Mbps (skipping all B-frames)
TBR for speed-up factor F = 12:	0.167 Mbps (skipping all P-frames and I-frames)

Results and Discussion

The results of our experiments are outlined in Tables 1-3. Table 1 compares the overall SNR of the layered coder with the SNR achieved with a comparable MPEG2 single layer coding scheme. The 3 layer Frequency Scalability scheme provides the possibility to decode only a subset of the layers for Resolution Scalability or SNR Scalability purposes. Dependent on the test sequence the quality of the reconstructed highest resolution video is decreased by approximately 0.65 dB compared to the single layer coder.

Figures 2 and 3 relate to the FF/FR mode simulation using the Frequency Scalability coding scheme. Only the lowest layer containing as a maximum the lowest 2x2 DCT coefficients was decoded. The video can be displayed at quarter, half or full spatial resolution dependent on the size of the inverse DCT chosen in the decoder. The actual bit rate used for decoding in FF/FR mode is compared to the theoretical "optimal" target bit rate TBR for sequences "Flowers" and "Calendar". The quality of the FF/FR video was good - D1 tapes for demonstration are available at the MPEG meeting.

The results reported are preliminary and do not involve bit rate control of the lowest 2x2 layer. Still it is evident that the actual speed-up bit rate is already very close to the theoretically desirable bit rate TBR (Figures 2 and 3). Means of controlling the bit rate to meet the TBR for the particular speed-up factors precisely are readily available within the Frequency Scalability syntax. The implemented layering scheme also allows the flexible allocation of DCT coefficients into the lowest 2x2 layer. If desirable only the first DCT coefficient (DC) can be transmitted in this layer to reduce the access bit rate as well as to reduce the complexity of a special purpose FF/FR decoder.

	Bit rate	**SNR** (Flowers)	**SNR** (Calendar)
Single Layer:	4 Mbps	28.96 dB	28.51 dB
FS Layered Coder:	4 Mbps	28.35 dB	27.85 dB

Table 1: *Efficiency of Frequency Scalability layered coding scheme compared to single layer implementation. test sequences were "FLOWERS" and "CALENDAR"*

	TBR	**Layered coder speed-up Bit rate**
speed-up factor F= 3:	0.667 Mbps	0.805 Mbps
speed-up factor F=12:	0.167 Mbps	0.178 Mbps

Table 2: *Bit rates achieved with the Frequency Scalability scheme for sequence "FLOWERS" . Lowest layer decoded only (I-frames and/or P-frames depending on the speed-up factor).*

	TBR	**Layered coder speed-up Bit rate**
speed-up factor F= 3:	0.667 Mbps	0.779 Mbps
speed-up factor F=12:	0.167 Mbps	0.185 Mbps

Table 2: *Bit rates achieved with the Frequency Scalability scheme for sequence "CALENDAR". Lowest layer decoded only (I-frames and/or P-frames depending on the speed-up factor).*