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Dual frame motion compensation for a rate switching network

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Abstract—Standard video coders often use the immediate past frame as a reference frame with motion compensation for video encoding. In this paper, we use dual reference frame motion compensation in the context of high bandwidth to low bandwidth switching such as from an Ethernet connection to a GPRS system. The implementation is based on MPEG-4. Simulation results show that there is a significant gain in the PSNR for relatively static video sequences.

I. INTRODUCTION

Standard video coders use temporal coding with motion compensation to achieve compression gains. This is based on the assumption that the past frame is highly correlated with the current frame. We propose to use dual frame motion compensation in wireless network settings that experience significant transitions in network capacity, such as those produced by network handoffs while using services such as Always Best Connected (ABC) [1].

A. The ABC network

With the widespread use of wireless access networks and the deployment of 3G services, connectivity service to the Internet with mobile devices such as PDAs and laptops needs to be maintained. The ABC service assists the user by automatically handling selection of access networks based on network availability and user preferences. Table I shows the various access networks supported by the ABC service.

The ABC network provides the framework for a user who wants to connect to a service to be able to choose network access and devices in a way that best suits his or her needs, and to change networks when something better becomes available.

Wireless Access Network	Bandwidth
WLAN	11Mbps - 1Gbps
Ethernet	10Mbps
HDR	500kbps
1xRTT	64kbps
GPRS	16kbps

TABLE I
NETWORKS SUPPORTED BY THE ABC FRAMEWORK

B. Dual frame motion compensation

In multiple frame prediction, the encoder uses more than one reference frame for motion compensated prediction. A dual frame encoder is a special case of a multiple frame encoder, in which two frames are used for motion compensation; they are often called the short-term past frame and the long-term past frame.

The idea of using a long-term past frame as an additional reference frame for motion compensation was considered in several papers [2], [3], [4], [5] as well as in the recent H.264 standard. [2] is one of the earliest papers to employ multiple frames for motion compensation to reduce the number of bits required to code the difference signal. Substantial coding gains were reported. In [3], a multi-frame extension was proposed to the single frame reference temporal coding. This was shown to yield improved compression efficiency because of the extended search provided by additional frames for Block Motion Compensation. It was further shown that this multi-frame extension was robust to wireless channel losses, where the channel was modelled as a multi-state Markov chain. Error resilience was obtained by randomly choosing among the stored frames

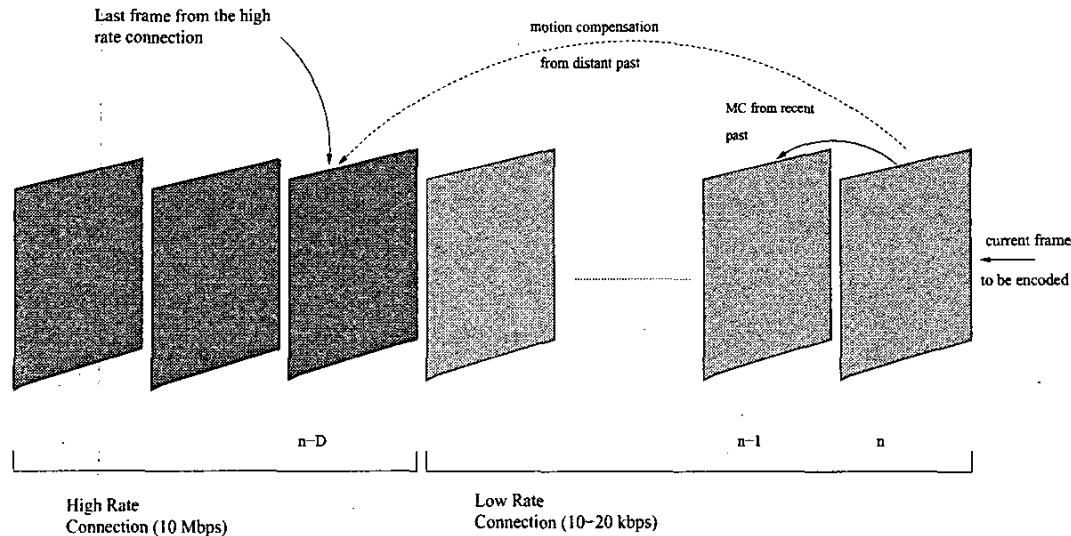


Fig. 1. Dual Frame Encoder schematic

used in multi-frame coding. In [4], the concept of the dual frame was simulated in a low bandwidth situation by Motion Compensated prediction using block partition prediction and utilization of two time differential reference frames. The coding scheme was found to improve the quality of object boundaries. Means for controlling the time delay involved in transmitting the motion vectors as side information were presented in [5]. A rate constrained motion estimation method was employed to control the bit-rate of the motion vector coding which may become prohibitively large for low bandwidth situations. The issue of using multiple frame motion compensation in the context of optimal inter/intra mode selection within a rate distortion framework was studied in [6]. It was shown that the above method improves the compression performance of the coder.

In contrast to previous work, we propose to use the dual frame concept in wireless network settings that experience significant transitions in network capacity, such as those produced by network handoffs while using services like Always Best Connected (ABC) [1]. By using dual frame encoding in this context, the system can significantly improve the quality of frames transmitted immediately after the network handoff and smooth the abrupt and severe transition in network capacity.

II. METHODOLOGY

In our approach, the long-term past frame is assigned to be the last frame coded just prior to the network switching from the high bandwidth to the low bandwidth mode, as illustrated in Figure 1. For each MacroBlock (MB) in a predictive frame, a search is conducted over both the immediate past and the long-term past frames, and the better matching block is chosen.

A video encoder operating under services like ABC must be robust to bandwidth changes of multiple orders of magnitude. We assume that the ABC network provides a timely delivery of packets with minimal loss. To counter the huge swings in bandwidth, we assume that the quantization parameter for each frame can be varied over its full range (1-31) as opposed to a standard compliant encoder which restricts the change in the quantization parameter value to 25% of the previous value.

To evaluate the effectiveness of the dual frame buffer technique, we simulated it by modifying the standard MPEG-4 coder. The MPEG-4 coder uses the rate control method employed in [7]. We considered each frame as a single object for the MPEG-4 encoder. We allocated additional memory for the long term frame. An extra bit is transmitted per inter coded MB to inform the decoder which frame it referenced. The intra refresh period was set to

100. Lowering the intra refresh period enhanced the performance of the dual frame encoder. But frequent intra refresh results in higher bit rates which would exceed the bit rates available for a GPRS system.

As inputs to the simulator, we used the News, Container and Foreman sequences. The News sequence consists of periodic background changes with news readers in the foreground. Because the foreground is fairly static, we expect the dual frame buffer to be effective for the foreground for some time after the rate drop occurs. Also, the background shows a dancer who revolves around; the dancer returns to the starting position and then repeats, so we expect the dual frame encoder to perform well for this repeating background. To investigate the effect of scene changes, we used the Foreman sequence. This sequence shows a man talking in a fairly static background with a scene change towards the end. The Container sequence depicts a ship moving slowly in the ocean and we used this to see the effect of having no significant background change.

The format of the test sequences is QCIF. The frame rate was 10 frames/second. To investigate the effects of switching to different low bandwidth networks, we simulated switching from 1 Mbps to low bandwidth networks ranging from 10 kbps (GPRS) to 150 kbps (1xRTT CDMA). We encoded each of these sequences using our dual frame buffer coder as well as with a conventional MPEG-4 coder for comparison.

III. DISCUSSION OF RESULTS

Figures 2 through 7 show the results of the dual frame buffer simulation. The high bit rate for all of the plots shown is 1 Mbps. The low bit rate for the plots in Figures 2, 4, and 6 is 16 kbps, and the low bit rate for Figures 3, 5, and 7 is variable as depicted on the x-axis.

Figure 2 shows the PSNR (in dB) for each decoded frame of the News sequence, for the MPEG-4 standard coder and the dual frame encoder. Figure 3 is a plot of the difference in PSNR between the standard MPEG-4 coder and the dual frame coder as the rate is changed for the News sequence.

The News sequence shows gains primarily after the 150th frame because, when the dancer returns to the starting position, the background of the image closely matches the long term reference background. This is witnessed by the sharp spike at frame 150

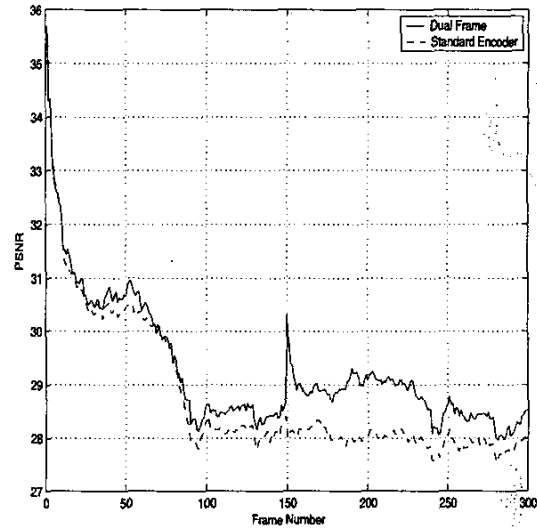


Fig. 2. PSNR versus frame number for the News sequence.

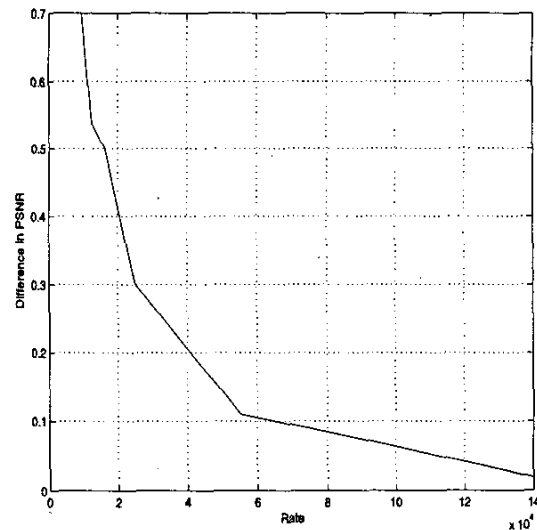


Fig. 3. Average difference in PSNR between the dual frame coder and the standard coder as a function of the bit rate of the low rate connection for the News sequence.

in the News sequence (Figure 2). This gain in PSNR propagates to subsequent frames and hence the decoded quality remains higher for the dual frame encoder. Figure 3 shows the difference in PSNR (PSNR for the dual frame encoder minus PSNR for the conventional single frame encoder) for the News sequence, as a function of the bit rate of the low

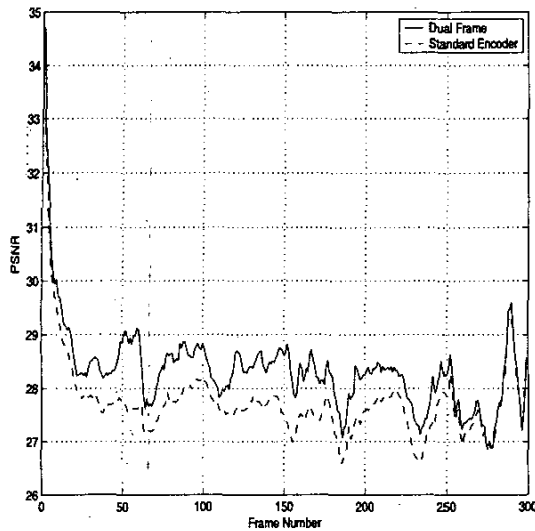


Fig. 4. PSNR versus frame number for the Foreman sequence.

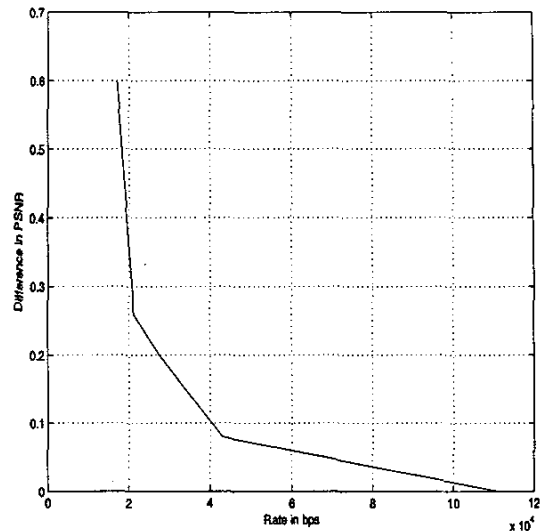


Fig. 5. Average difference in PSNR between the dual frame coder and the standard coder as a function of the bit rate of the low rate connection for the Foreman sequence.

rate connection. For this plot, the PSNR is averaged over the 300 frames in the sequence. The PSNR gap diminishes as the low rate connection has increasing rate.

Figures 4 and 5 are analogous to Figures 2 and 3, but for the Foreman sequence. This sequence initially shows gains of around 1 dB in PSNR. The gain disappears completely towards the end of the sequence (around frame 275) because of a change in the background. The Container sequence (Figures 6 and 7) shows similar results. The initial gains are substantial, but the value of the long term frame diminishes over time. As expected, the PSNR gains in Figure 7 decrease as the rate of the low bandwidth connection increases.

IV. CONCLUSION

In this paper, we presented a dual frame buffer motion compensation system used to improve video quality after network handoffs in services like ABC when they switch from a high data rate to a low rate. We evaluated the technique on three video sequences that vary in their characteristics. We found that retaining the high quality frame to be used as the long term past frame for the dual frame encoder results in better video quality for up to a few hundred frames as quantified by the PSNR of the decoded sequence. The technique requires a small cost in memory (both at the encoder and decoder) to retain

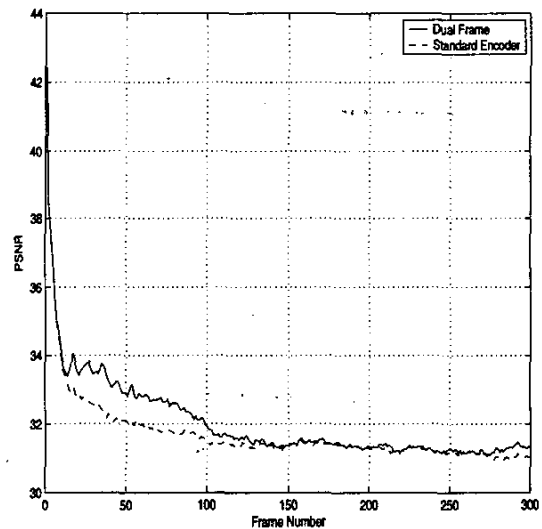


Fig. 6. PSNR versus frame number for the Container sequence.

the dual reference frame, and a small cost in encoder complexity to search the second reference frame for the best match block.

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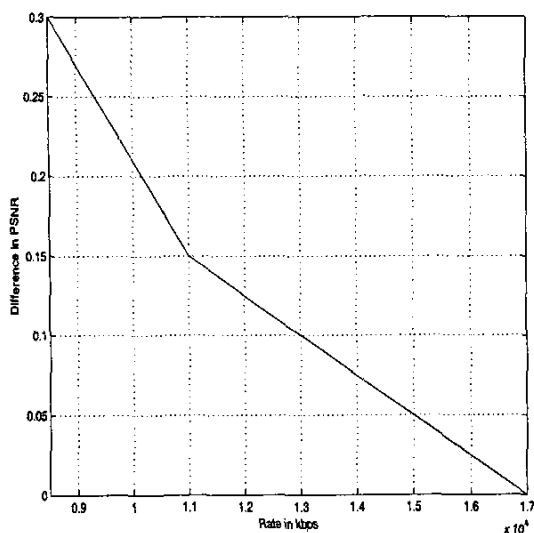


Fig. 7. Average difference in PSNR between the dual frame coder and the standard coder as a function of the bit rate of the low rate connection for the Container sequence.

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