

Error resilient Video codec for resource constrained system using periodic Intra Frame based prediction

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Abstract – Current research on Video Compression algorithms focus on optimizing the efficiency. Research in the area of error resilience of compressed video streams target errors over the air or network. They do not take into account the resource constraints of devices. As mobiles phones are becoming powerful and the data bandwidths are increasing, a lot of video applications are becoming feasible however interoperability with previous generation of cell phones becomes an issue. It is essential to devise video compression algorithms that could scale appropriately for constraints such as CPU capacity and power savings. In this Paper, we propose a codec that is scalable across several platforms with little impact on distortion and show that it is better over existing techniques during heavy loss conditions.

I. INTRODUCTION

In the current Video compression standards such as MPEG-2, MPEG-4, hybrid coding techniques are used where both temporal and spatial redundancy is minimized for higher compression [1]. In temporal prediction technique, a frame is either coded with no other frame dependency (Intra Frame) or coded with dependency on past frame (P Frame) or coded with dependency on past and future frames (B Frame).

Depending on the framing structure where a combination of P and B frames are repeated periodically within two I Frames, the frame dependency exists between two Intra frames. During the transport of video packets or for any other reason, if there is loss of data, the error is propagated until an error free Intra frame is decoded [2]. Also, in resource constrained systems such as mobile phones, due to power and cost constraints they deploy processors with low processing power that cannot support the decoding of all the frames in the video clip. If all the frames are not decoded, due to frame dependency the error propagates and results in distortion.

H.263 proposes the concept of reference picture selection (RPS) for error resilience where a past frame is referenced if previous picture is distorted [3]. However, such technique is only used during loss conditions and requires feedback from decoder channel. H.264 standards specifies prediction from multiple previous frames for efficiency purposes and the error resilience aspects of such scheme is an actively research topic [4]. However, due to frame dependency does persist in many ways and distortion propagates until an I Frame is decoded.

II. PROPOSED ALGORITHM

In this paper, we propose a new scheme that deploys periodic Intra frames and prediction of all the frames within the period is based on the Intra frame as shown in Figure 1 Figure 1 (PIFBP). This techniques limits errors within P frame to that particular frame and eliminates distortion propagation. This improves error resilience at the cost of coding efficiency. This scheme is helpful if the frames are not lost or not decoded in order as is the case in constrained devices. The proposed scheme is a compliant with the H.264 and H.263 standards however is variation of framing structure. Due to this structure, the efficiency is lower due to less temporal correlation between reference frame and predicted frame however during loss and resource constraints, the new schemes performs much better.

Shown in Table 1, the comparison between Intra Frame coding and Interframe coding techniques using MPEG-4 simple profile. The test sequence used for simulations is FOREMAN sequence with QCIF resolution with original sequence at the rate of 30 fps (frames per second) but the encoded frame rate is 15 fps. A total of 200 frames are used for the simulations, (random loss is generated) each of the test cases are ran 30 times and average is reported in the paper at the bit rate of 128 kbps.

The results are shown for error free and 20 % frame loss condition. The case for 20 % frame loss comes from a scenario of a mobile device that can support 12 fps whereas the content is at 15 fps and that constitutes 20% loss. In the error free conditions, the Intra frame coding is less efficient than Intra frame coding however during lossy conditions the new schemes performs much better. This is due to non-propagation of distortion in the new scheme. At this point, it is worth noting that Intra frame period of 1 equals coding with just Intra frames resulted in only 96 frames instead of 200 frames eventhough it would not have any error propagation.

Table 1: Effect of periodicity and frame losses on PIFBP and MPEG-4 SP (128 kbps) at 15 fps

VOP Periodicity	PSNR (Inter Frame Prediction) (Error Free)	PSNR (PIFBP) (Error Free)	PSNR (Inter-Frame Prediction) (20 % loss)	PSNR (PIFBP) (20 % loss)
0	32.19	27.85	20.81	26.56
5	30.51	30.05	25.42	28.17
10	31.25	29.88	24.04	27.44
15	31.52	29.65	22.62	26.14
20	31.73	29.21	22.85	27.9

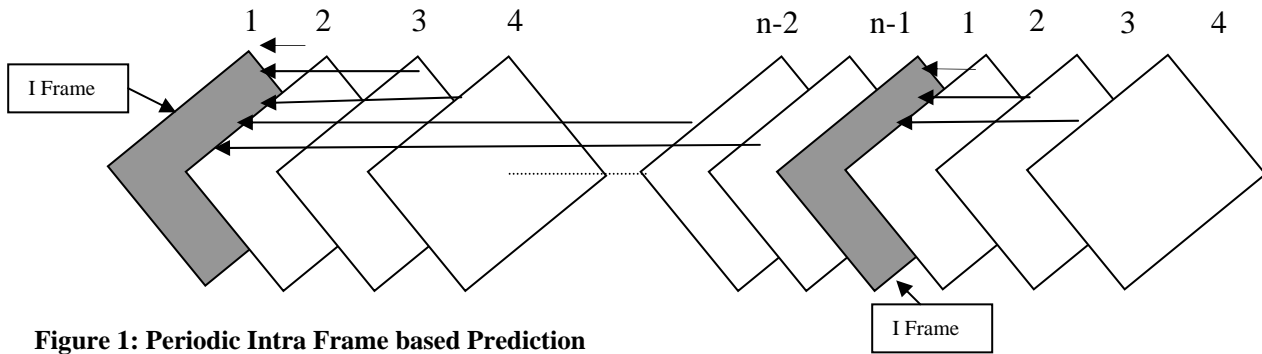


Figure 1: Periodic Intra Frame based Prediction

This table shows that Intra frame based prediction is less efficient than Inter frame based prediction however in lossy conditions, due to the error resilient framing structure PIFBP performs much better and shows consistent quality and would hide device conditions from the presentation.

III. SIMULATION RESULTS

To simulate losses in constrained devices, that do not have processing power to render higher frame rate video bit streams, a frame loss simulation are conducted. In the frame loss scenario, due to several reasons such as several applications, lower processing power, delay over the networks, frames are skipped to achieve synchronization with the audio. The skipping of P frame or an I frame in the conventional schemes would cause distortion and this would propagate until an I frame is decoded. The skipping of B Frames does not cause any distortion however they are not considered due to the complexity involved and are not required for Simple Profile.

In the new scheme however, since within the period, the P frames are dependent on the I frame, skipping of a P frame would not result in distortion. In a resource constrained system, the I frames will be given priority and P frames are skipped over I frames to achieve synchronization.

Figure 2 shows the performance of MPEG-4 Simple Profile codec under frame loss conditions. By multiplying the loss rate and number of frames in the test sequences, the number of frames to be dropped are determined. A random number generator is used for figure out the frame that will be dropped. The PSNR of the resulting sequence is calculated using original sequence. These experiments are ran 30 times to get more accurate results and average over trails is reported in this paper. The experiments are repeated for bit rates of 64 kbps, 128 kbps and 384 kbps and for frame rates of 5, 10 and 15. For simplicity, Error resilience features such as Intra block refresh have been disabled.

Also plotted is the average PSNR of PIFBP (with VOP period of 5) with and without preservation of I frames. With preservation of I Frames, the new schemes perform much better with error losses of 3 % loss and above. The PSNR remains much more consistent and has a graceful degradation based on network and system conditions.

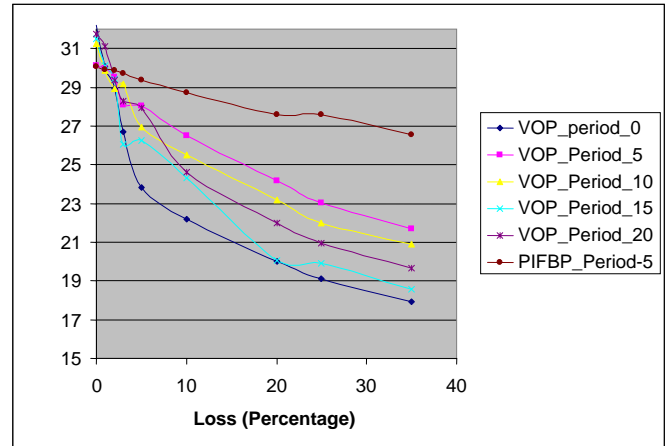


Figure 2: Performance under loss of Inter / Intra frame coding (Data rate = 128 kbps, fps =15 fps)

Error! Reference source not found. shows the comparison of performance of Inter Frame decoding with varying Intra Frame periods with PIFBP scheme with and without preservation of I Frames. The PIFBP scheme with outperforms other schemes with Unequal Error protection(preservation of high frames) outperforms rest of the other schemes.

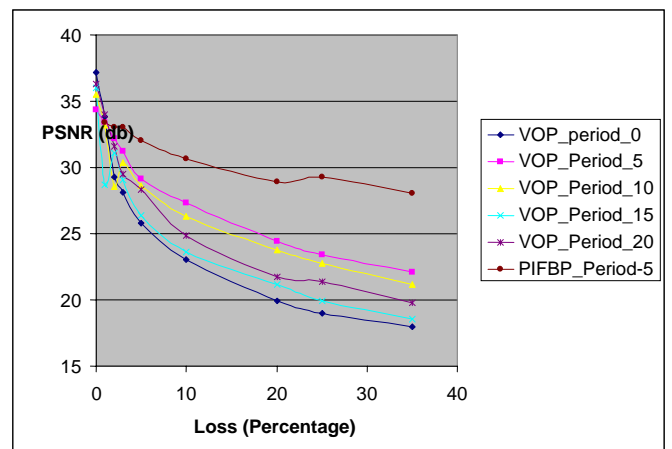


Figure 3: Performance under loss of Inter / Intra Frame coding (Data rate = 384 kbps, fps = 15)

In Simple Profile where there are no frames, this codec can skip frames without resulting in distortion. In unreliable network or CPU with limited / unreliable resource, this codec is certainly useful. If the constraints of the end display are unknown, this offers a scalable approach where the overhead is accounted in the source file creation.

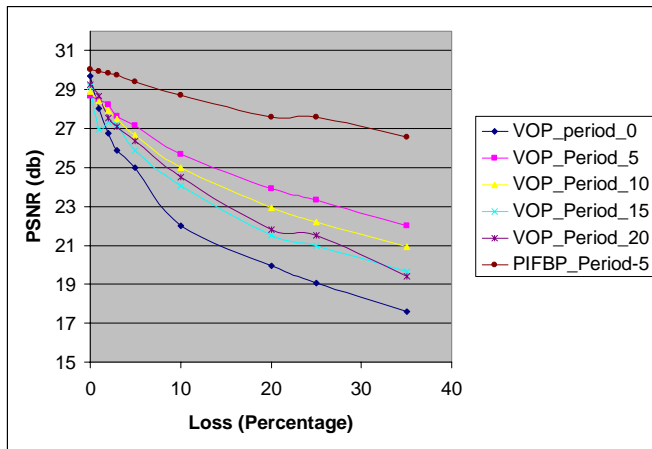


Figure 4: Performance under loss of Inter / Intra Frame coding (Data rate = 64 kbps, fps = 15)

Shown in Figure 5 Performance under loss of Inter / Intra Frame coding (Data rate = 64 kbps, fps = 10) is the performance of the new scheme when the data rate is 64 kbps at 10 fps. As the target frame rate is lowered, the new scheme does not perform as well as higher frame rates however it still performs better than existing scheme at different VOP rates.

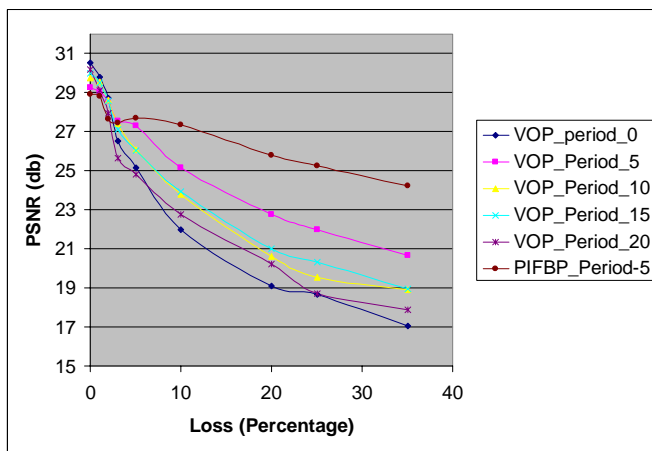


Figure 5 Performance under loss of Inter / Intra Frame coding (Data rate = 64 kbps, fps = 10)

Shown in Figure 6 is the plot of PSNR values for individual frame coded at 128 kbps with 15 % frame loss for PIFBP scheme of VOP frequency of 5 and conventional scheme with VOP frequency of 5. The figure clearly shows that there is less variation of PSNR in the new scheme versus the Inter

frame based prediction coding and average quality is much better in lossy conditions. Also, shown in When loss conditions are less than 5 %, the new scheme does worse than the old scheme however as the loss rate increases the quality remains the same in the new scheme making it desirable in lossy conditions whereas the degradation in traditional schemes is significant.

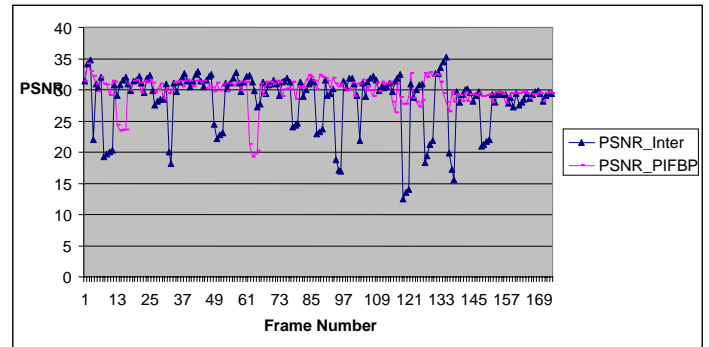


Figure 6: Comparison of PSNR figures for individual frame for Intra and Inter schemes for FOREMAN sequence at 128 kbps, 15 fps and 15 % loss with VOP periodicity of 5.

It is worth noting that combination of both schemes can be done that would work better in all conditions. Depending on the channel conditions, if the loss rate is relatively low (less than 5 %), conventional scheme is used but is switched to the PIFBP scheme when loss rate is more than 5 %. The combined scheme depending on loss conditions would outperform both scheme in all conditions.

Even though the use case of resource constrained devices are referred, the PIFBP scheme can be applied any network that can have lossy conditions and the end devices have limited processing power and capability. In networks with lossy conditions, burst errors could result in dropping of a frame. Also, due to VLC, a bit error could result in losing synchronization and dropping of the frame[13][14]. In such case, in the new scheme, the frame could be skipped or simple error concealment technique could be applied without impact on overall quality. This is not noticeable by the end user as opposed to distortion propagation that is noticeable as it spans several frames[15].

The Intra Block refresh method improves quality in frame loss scenarios[7] as shown in Table 2 however still inferior to PIFBP scheme.

Table 2: Effect of Intra Macro Block Refresh rates on different frame loss rates of Inter Frame prediction (Foreman, 128 kbps, 15 fps) (random Losses averaging over 30 tries)

Random Loss Rate	PSNR(0)	PSNR(0) with Intra Refresh	PSNR(0) with Intra Refresh + RVLC + Data Partitioning	PIFBP Scheme with no error resilience features
0	32.19	31.99	31.99	30.05
1	30.08	30.52	30.54	29.92
2	28.92	29.73	29.12	29.85
3	26.70	28.50	28.76	29.73
5	23.84	26.98	27.04	29.39
10	22.18	24.25	24.34	28.73
20	20	21.49	21.63	27.60
25	19.12	20.89	20.52	27.59
35	17.91	19.57	19.69	26.56

As you can see from the above table adding the feature of random Intra block refresh lowers PSNR of 0.2 db for Error free quality but improves overall quality (up to 3 db at 5% loss) when there is loss. Since frame loss is simulated, the other MPEG-4 Error resilient features such as RVLC, Data partitioning [14] do not add any significant improvement in quality during loss. The PIFBP Scheme performs much better in frame loss scenarios.

IV. CONCLUSION AND FUTURE WORK

The proposed scheme does offer much better performance than conventional scheme in lossy conditions. It offers consistent performance in error-free and error environments by shielding the user from device limitations. The proposed scheme is quite simple and can be used to drop a frame if there are errors in the frame. The existing error resilient techniques require processing power and would drain the current whereas the new scheme consumes less power. The resulting gains due to error concealment are depend on where error has occurred and are hard to quantify. The dependency make it more difficult and with the new scheme this can be avoided.

This frame skipping can be done at any point in network such as server, intermediate points and client. The RTP/UDP/IP scheme can be used to packetize one frame per packet and can be dropped at server for reasons such as server load, congestion on the network and bandwidth adaptation. Since the packets are on frame boundaries, they could be dropped at intermediate points because of network congestion etc. The client can also drop frames because of power, bandwidth and other constraints. The new scheme does much better over traditional schemes during such losses and is scalable. The PIFBP scheme is useful when the capabilities of the end devices are not known. If the content is placed on the server with a target frame rate with PIFBP, devices that can support lower and higher frame rates can download the same content and the content can adapt to the device characteristics. Also, if there are devices that belong to the same network but have

different processing capabilities, interoperability is an issue. The new scheme make content creation easier independent of devices capabilities.

The overall efficiency could be improved in the PIFBP schemes by predicting the I frames based on previous I frames as shown in Figure 7. This would result in separate threads, one is thread of anchor frames that is less frequent and preserved using the unequal error protection or retransmissions. Another thread is frames that are between two anchor frames and are dependent on anchor frames. Another area of research is determining optimal frequency of Intra frame based on the video characteristics and quantifying the distortion.

REFERENCES

- [1] Yao Wang and Qin-Fan Zhu, "Error Control and Concealment for Video Communications: A Review", *Proceedings of the IEEE*, Vol. 86, NO. 5, May. 1998.
- [2] Bansal, Pankaj, Narendran, M. R. and Manohar Murali N. K., "Improved Error Detection and Localization techniques for MPEG-4 Video", *International Conference on Image Processing.*, Vol. 2, Pages:II-693 - II-696, 22-25 Sept. 2002
- [3] Chun g-How, J.T.H. and Bull, D.R., "Robust H.263+ video for Real-Time Internet Applications", *Proceedings of International Conference on Image Processing*, vol. 3, pp. 544-547, Sept. 2000.
- [4] Wiegand, T., Sullivan, G.J., Bjntegaard, G. and Luthra, A., "Overview of the H.264/AVC video coding standard", *IEEE Transactions on Circuits and Systems for Video Technology*, Volume: 13, Issue: 7, July 2003, pp. 560 – 576
- [5] G. J. Sullivan and T. Wiegand, "Rate-distortion optimization for video compression," *IEEE Signal Proc. Magazine*, Vol. 15, no. 6, pp. 74-90, Nov. 1998
- [6] Qian Zhang, Zhu Ji, Wenwu Zhu and Ya-Qin Zhang,, "Power-minimized bit allocation for video communication over wireless channels", *IEEE Transactions on Circuits and Systems for Video Technology*, Volume: 12, Issue: 6, Pages:398 – 410, June 2002
- [7] Zhao, C, Ngan, K.N, Zhang, J, Mathew, R. and Zhang, X., "Using inter-frame dependence history to select intra-refresh blocks" *Electronics Letters*, Volume: 38, Issue: 22 -24, Oct 20.
- [8] "Information Technology – Generic coding of moving pictures and associated audio information – Part 2: Video", ISO/IEC DIS 13818-2, 1994
- [9] Talluri. R, "Error Resilient coding in the ISO MPEG-4 standard", *IEEE Communications Magazine*, Vol. 36, Issue. 6, pages 112-119, June 1998
- [10] Freytes, M., Rodriguez, C.E., Marques, C.A., "Real-time H.263+ video transmission on 802.11 wireless LANs", *Proceedings. International Conference on Information Technology: Coding and Computing*, pp. 125-129, 2-4 April 2001.
- [11] Guy Cote, Shahram Shirani and Faouzi kossentini, "Robust H.263 video communication over mobile channels" [1999]
- [12] Taal, J.R., Haratcherev, I., Langendoen, K., and Legendijk, R., "Quality of service controlled adaptive video coding over IEEE 802.11 wireless links", *Proceedings. Of International Conference on Multimedia and Expo, 2003.*, pp. 189-192, Volume: 1, 6-9 July 2003.
- [13] Bansal, P.; Narendran, M.R.; Murali, M.N.K.," Improved error detection and localization techniques for MPEG-4 video", *Proceedings. 2002 International Conference on Image Processing. 2002.*, Volume: 2, 22-25 Sept. 2002 Pages:II-693 - II-696 vol.2
- [14] Brailean James, "Wireless Multimedia utilizing MPEG-4 Error resilient Tools", *IEEE Transactions*, 1999.

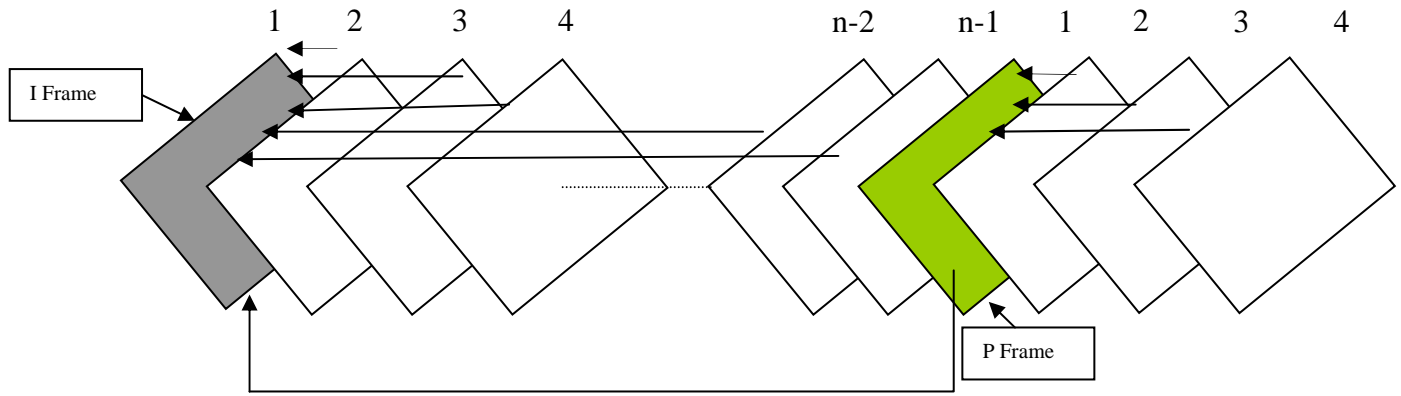


Figure 7: Periodic Anchor frame based prediction (PAFBP)