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# Demonstration of Ameliorating Packet Loss in a Video Stream by Using Interleaving

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## 1. INTRODUCTION

Multimedia data transmitted over the Internet often suffers from delay, jitter, and data loss. Data loss in particular can be extremely high on the Internet, often as high as 40% [6]. Unlike traditional applications, multimedia applications can tolerate some data loss. A small gap in a video stream may not significantly impair media quality, and may not even be noticeable to users. However, too much data loss can result in unacceptable media quality. A number of techniques exist to repair packet loss in a media stream [5]. These techniques have proven to be effective for audio stream data loss, but many have yet to be applied to video.

Interleaving assumes that better perceptual quality can be achieved by spreading out bursty packet losses in a media flow. In other words, several small gaps are better than a big gap in a multimedia flow. For example, assume there is a frame consisting of several characters of information:

**WorcesterPolytechnicInstitute**

Assume that during transmission several characters in the frame get lost:

**terPolytechnicInstitute**

The first word is then very hard to reconstruct. However, the original frame can be interleaved as:

**otlhnuWsocItreynstcrtiteePeci**

After applying the same loss to the interleaved frame, the frame then can be reconstructed as:

**WrceserPoytecnicIstitute**

It is much easier to “interpolate” the missing letters. The

same idea has been applied to audio streams as a loss recovery technique [4]. However, it is known that the human visual system is less sensitive than the human auditory system, thus a small gap in a video stream maybe less noticeable than a small gap in an audio stream, suggesting that interleaving may be more effective for video than for audio.

Multimedia streams are compressed before being transmitted over the network. The MPEG (Motion Picture Expert Group) achieves high compression rate by exploiting temporal redundancies of subsequent pictures. MPEG distinguishes 3 main frame types of image coding: I-frame, P-frame, and B-frame. I-frame stands for Intra-coded frame which are self-contained. P-frame stands for Predictive-coded frame. The encoding and decoding of P-frames requires the information of previous I-frames and/or all previous P-frames. B-frame stands for Bi-directionally predictive-coded frames. The encoding and decoding of B-frames requires the information of the previous and following I- and/or P-frame.

In our research, we propose a video interleaving approach to enhance repair from loss. We design and implement an interleaving strategy for video streams. The sender re-sequences the video stream before transmitting, so that original adjacent units are separated by a guaranteed distance in the transmitted stream, and the receiver returns them to their original order. The basic idea of interleaving is to spread out one big gap in the media stream into several small gaps. In this way the effect of the loss of multiple consecutive frames will be ameliorated, and the perceptual quality will be increased. Our interleaving approach is also combined with repetition error-recovery, in which a lost frame is recovered by repeating the previous consecutive frame. For example, with the Group of Picture (GOP) pattern IBBPBBPBB, Figure 1 demonstrates interleaving and the result of the first P-frame lost within a video stream, and Figure 2 shows the situation of the same P-frame lost in the same video stream without interleaving.

## 2. EVALUATION

Since it is the end-user who will determine whether a service or application is a success, it is vital to carry out subjective assessment [1] of the multimedia quality afforded by our repair approaches. In our work, we evaluate the effects of video interleaving on the quality of video streams through

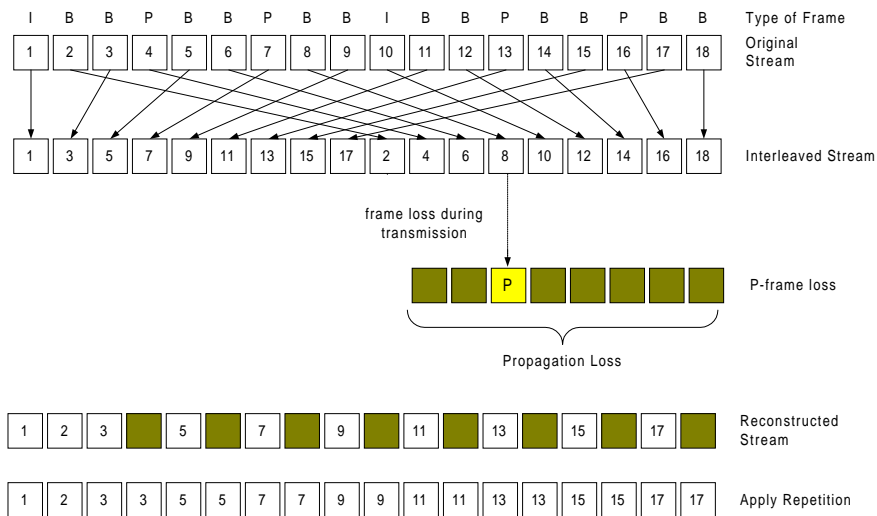


Figure 1: Effects of the first P-frame lost when using interleaving

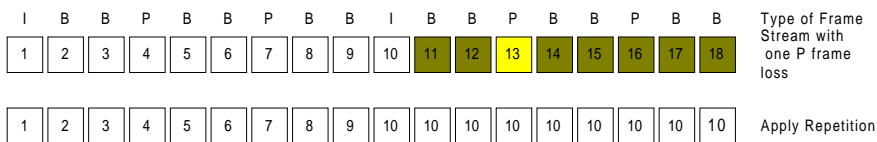


Figure 2: Effects of the first P-frame lost without interleaving

studies in which users evaluate the video quality.

A process for applying interleaving is shown in Figure 3. For our system, video clips used in our implementation were recorded from TV and then encoded into MPEG-1 format. The encoding tool we used was Berkely MPEG-1 Video Encoder [3], and the decoding tools we used was Berkeley MPEG-2 player [3] and the Microsoft Media Player. As the process demonstrated in Figure 3, we first break the original .mpg file into separate .ppm files using the MPEG decoder, one file for each frame in the video stream. In the next step, we apply our interleaving algorithm as appropriate to the .ppm sequences. Then, we encode the modified .ppm sequences using the MPEG encoder to generate the .mpg file for transmission over the network. We apply a randomly generated loss rate to the video stream between sender and receiver, simulating a lossy network. After the receiver gets the video stream, the interleaving algorithm is again applied to the video stream to recover from any packets lost.

We chose three loss rates for examination based on previous Internet traces: 2%, 5%, 10% and 20%, which we call the *raw* loss rate. For example, if 10 out of 100 frames are lost through the network, the *raw* loss rate is 10%. However the loss of an I- or P-frame can leave the frames that are dependant on it useless, which results in an even higher loss rate shown to the end user.

Totally 32 users participated in the user study on interleaving. All users were graduate or undergraduate students with computer science backgrounds. Users were required to

watch a sequence of MPEG movie clips and evaluate the quality of each clip with a score between 0, the worst quality, and 100, the best quality. The study for interleaving was carried on an Intel PIII (800 MHz) running SuSE Linux 6.4 i686, which could play MPEG clips at 30 frames per second, and the player used was the Berkeley MPEG-2 player.

Figure 4 shows the comparison between interleaving repaired video clips and unrepaired clips. We also calculated 95% confidence intervals for each data point, depicted with an error bar. At loss rates of 5%, 10% and 20%, interleaving improves the quality of the video clips. At 5% loss, the average score for unrepaired clips is 59, by using interleaving, the average score improved to 76 (about 25%). And this improvement goes even higher to 39% at a loss rate of 10% and 38% at a loss rate of 20%. At a loss rate of 2%, although the average score for the interleaved clips is higher than that of the non-interleaved ones, the 95% confidence intervals for the two values overlap. A larger user study with more participants may be necessary to statistically separate the perceptual quality of the two loss rates. Interleaving even performs well at a loss rate of 20% in the presence of consecutive loss.

### 3. SUMMARY

We propose a video interleaving approach. Our interleaving approach re-sequence units in a video stream at the sender, transmits them through network to the receiver, and reconstruct the video to its original order. In this way, big gaps in a video stream due to consecutive frame losses can be spread out to several small gaps, thus improving the percep-

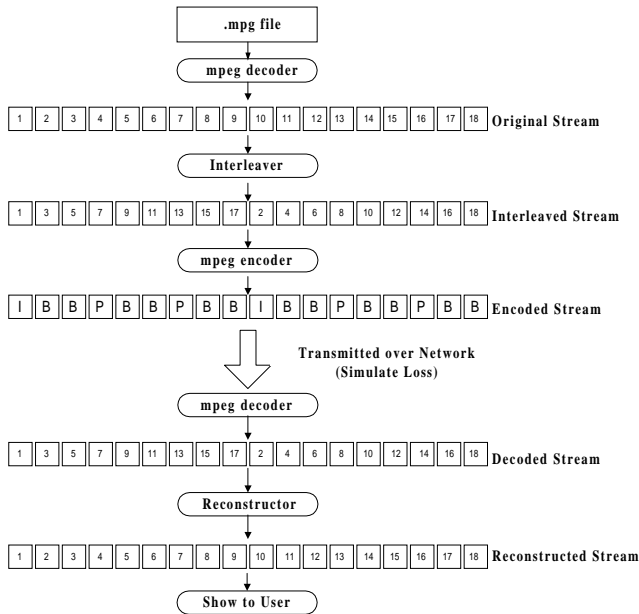


Figure 3: Video Repair

tual quality of the video stream. In the situation of random consecutive loss, our interleaving algorithm can improve the perceptual quality by about 25% at a loss rate of 5%, and about 40% at loss rates of 10% and 20%. Our results show that interleaving significantly improve the perceptual quality of Internet video, and it performs reasonably good in the case of consecutive loss, at the expense of increased latency.

#### 4. DEMONSTRATION

We include 5 video clips that demonstrate the effects of video interleaving on different loss conditions. The loss characteristics of each clip are included in the table below. Each video clip is encoded and played out at 30 frames per second. Observations on each from our user study results follows the table.

Video Clip	Percent Loss	Repair?	Score	Size (MB)
(1) "Perfect" clip	0	-	89	3.92
(2) Low loss, no repair	5%	no	59	3.62
(3) Low loss, repair	5%	yes	76	2.70
(4) Higher loss, no repair	10%	no	38	2.97
(5) Higher loss, repair	10%	yes	54	2.46

The "perfect" video means no loss. The low loss, no repair video has a loss rate of 5%. At this loss rate, the degradation in quality is quite dramatic. Users rated this clip an average of a 59, a drop in quality of nearly 35% versus a video clip with no loss. The third video clip has the same loss rate as the second one. However, by applying video interleaving on the clip, the 5% loss is noticeably repaired. Users found the quality of this video clip increased by approximately 30% over the video clip at the same loss rate without repair. The fourth and fifth video clips have the same loss rate of 10%, with video interleaving applied to the fifth video only. For

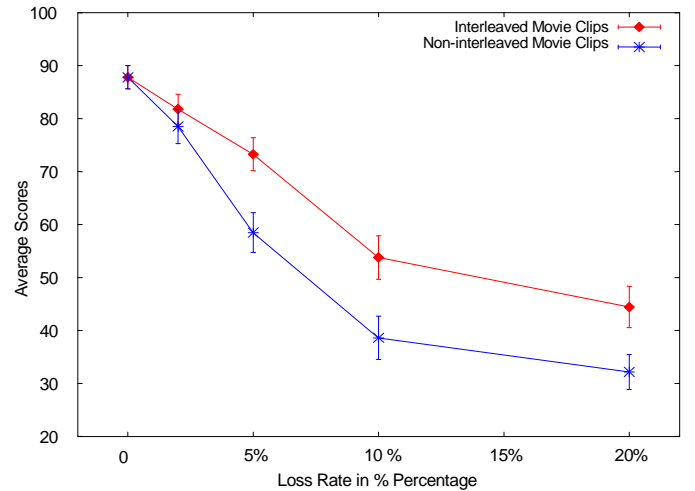


Figure 4: Effects of Loss Rates on Perceptual Quality

the fourth video clips, since no repair is applied, the video quality is severely degraded. Users rated the quality of this clip less than half that of a clip with no loss. For the fifth video clip, at 10% loss, although video interleaving cannot improve the video to a quality level anywhere near perfect, users still found the quality of this repaired clip 40% better than the fourth clip.

Further details on video interleaving and our sample videos can be found at: <http://rhine.wpi.edu/~yaliz/demo/>.

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