Using Redundancy and Interleaving to Ameliorate the Effects of Packet Loss in a Video Stream

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WPI

Typical Network Traffic

- Majority is text-based
  - File transfer, Email, Web…
- Reliability is critical
- Latency is not critical
- Transmitted Using TCP
  - Provide reliable service where all bytes arrive

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Multimedia Network Traffic

- High bandwidth
  - Can induce congestion → packet loss
- Latency is critical
- Loss is not critical
  - Can tolerate some
- Transmitted using UDP
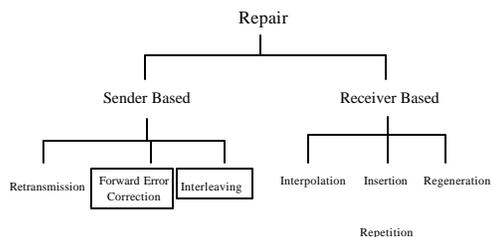 - Provide unreliable service where some packets may be lost
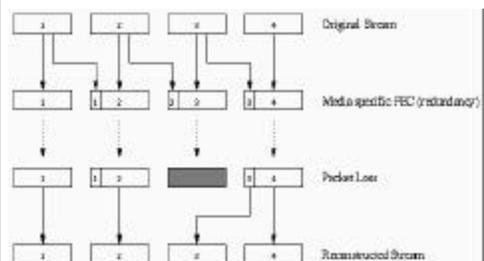
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Multimedia Over Internet

- Often suffer from delay, loss and jitter
  - degrading multimedia quality
- Loss has the most severe effects on quality
- Use loss recovery techniques to
  - Improve multimedia quality
  - Keep latency low

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Multimedia Repair Taxonomy

Repair

Sender Based — Receiver Based

Retransmission | Forward Error Correction | Interleaving   Interpolation | Insertion | Regeneration

Repetition

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Media Specific FEC

- Multiple copies of data
- Lower quality of secondary frames

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Idea of Interleaving

- Without Interleaving
- With Interleaving

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Audio Interleaving

Encode

Interleave

Transmit

Decode

Goal

- Above techniques have been done primarily to audio only
- Our goal:
  - Apply Interleaving and Redundancy to Video
  - Evaluate effects on perceptual quality
  - Evaluate system overhead

Groupwork

- What are the issues with applying video redundancy to video vs. audio?
- What are the issues with applying interleaving to video vs. audio?
- What would be a methodology for evaluating the benefit?
- What performance metrics should you have?

MPEG Encoding Techniques

- Intra-frame encoding
  - Based on current frame only
- Inter-frame encoding
  - Based on similarity among frames
- Frame types
  - I-frame (Intra-coded frame)
  - P-frame (Predictive-coded frame)
  - B-frame (Bi-directionally predictive frames)

Coding Dependency within GOP

| I | B | B | P | B | B | P | B | B | I |

- I frames (*Intra-coded frames*)
- P frames (*Predictive-coded frames*)
  Require information on previous I- or P- frames
- B frames (*Bi-directionally predictive-coded frames*)
  Require information on frames before and after

Loss Propagation

- Loss of one single frame result in multiple losses
  - Loss of P-frame
  - Loss of I-frame
  - B-frame loss has no propagation

I	B	B	P	B	B	P	B	B	I

Loss Propagation of Second P-frame

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Outline

- Introduction
- Background
- *Approach*
- System Overhead
- Perceptual Quality
- Conclusions

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Approach

- Apply interleaving and redundancy to video
  - Hypothesize will improve perceptual quality
  - Measure system overhead

- Build movies (next slide)
  - With loss, interleaved repair, redundancy repair
- Evaluate with user study
- Measure system overhead
- Analysis

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Repairing a Video Stream

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Video Redundancy

Repetition in the case of consecutive loss
- (if I frame, bad news)
Propagation in the case of I, P frame loss
- of quality or previous frame
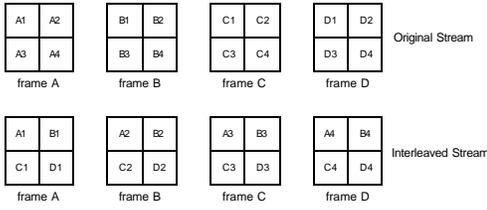
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Effect of Two Frames with Different Compression Rates

Two Frames with Different Compression Rates

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Interleaving Approaches

- *Partial-Interleaving* approach
  - Use sub-frame as basic interleaving unit
    + sub-frame consists of macro blocks
  - (Next slide)
- *Whole-Interleaving* approach
  - Use whole frame as basic interleaving unit
- Focus on Whole-Interleaving
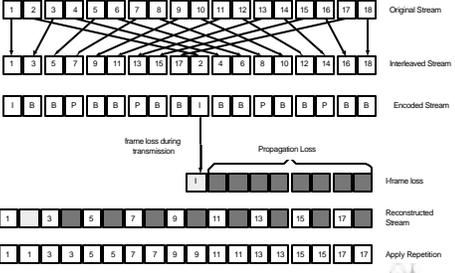 - (Rest of work)

Partial Video Interleaving

A1	A2		B1	B2		C1	C2		D1	D2	Original Stream
A3	A4		B3	B4		C3	C4		D3	D4	
frame A			frame B			frame C			frame D		

A1	B1		A2	B2		A3	B3		A4	B4	Interleaved Stream
C1	D1		C2	D2		C3	D3		C4	D4	
frame A			frame B			frame C			frame D		

Repetition and Partial Video Interleaving
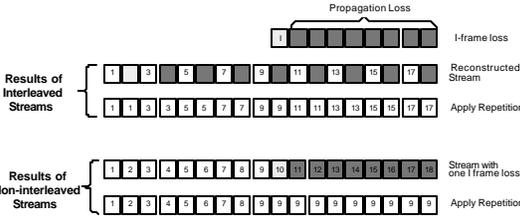
(4 repair pictures here)

Whole Interleaving

Effects of lost I-frame with whole-interleaving /distance=2

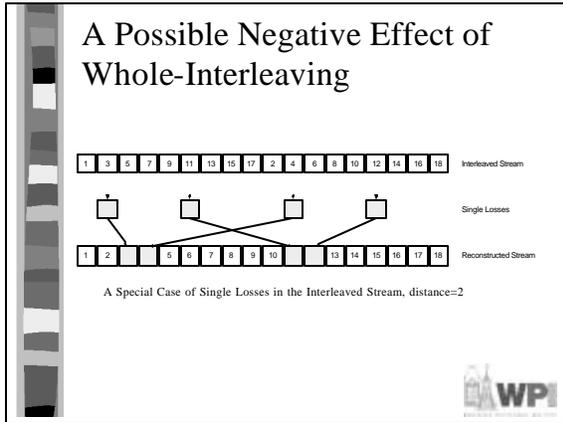## Effects of Whole-Interleaving

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Whole Interleaving Distance

Original Stream (GOP Size = 9)
1 2 3 4 5 6 7 8 9   10 11 12 13 14 15 16 17 18 ...

Interleaving Distance = 2
1 3 5 7 9 11 13 15 17   2 4 6 8 10 12 14 16 18 ...

Interleaving Distance = 5
1 6 11 16 21 26 31 36 41   2 7 12 17 22 27 32 37 42 ...

A Possible Negative Effect of Whole-Interleaving

| 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | Interleaved Stream

Single Losses

| 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 13 | 14 | 15 | 16 | 17 | 18 | Reconstructed Stream

A Special Case of Single Losses in the Interleaved Stream, distance=2

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MPEG Quality Vs. File Size

Redundancy Overhead per Frame

Redundancy Overhead per Movie Type
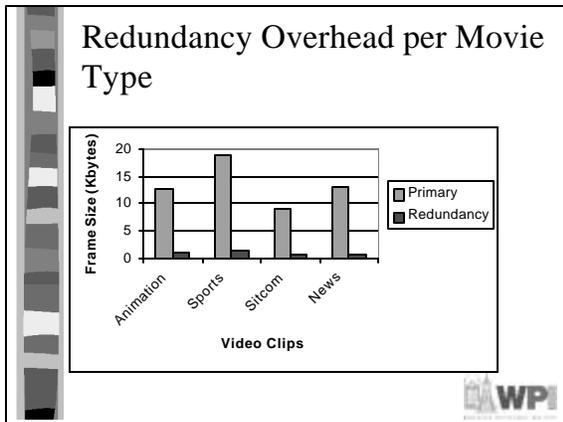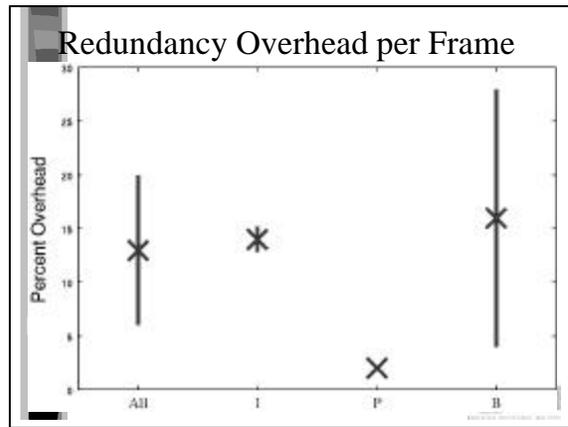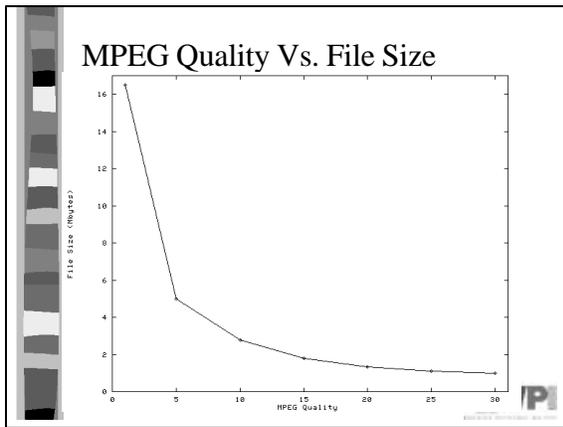
Interleaving Overhead

- About 15% bandwidth overhead
- Reason
  - Intra-frame encoding based on similarity among frames
  - Interleaving
    + Decrease similarities among consecutive frames
    + Result in bigger B- and P- frames

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | Original Stream

| 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | Interleaved Stream

Proposed Solution to Bandwidth Overhead

- Encode using different MPEG qualities
  - Original stream with MPEG quality 1
  - Stream with added repair with MPEG quality 2
  - File size decreases exponentially
 - Video quality slightly decreased
    + may be undistinguishable by users

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User Study for Redundancy

- We had over 40 users watch 22 video clips
- Video are from variety of television shows
- A video clip without loss is first displayed
- Video clips are of various loss rate and loss pattern.
  - Loss Rate: 1   10   20   20   20
  - Loss Pattern: 1   1   1   2   4

Perceptual Quality for Redundancy

Consecutive Loss and Redundancy
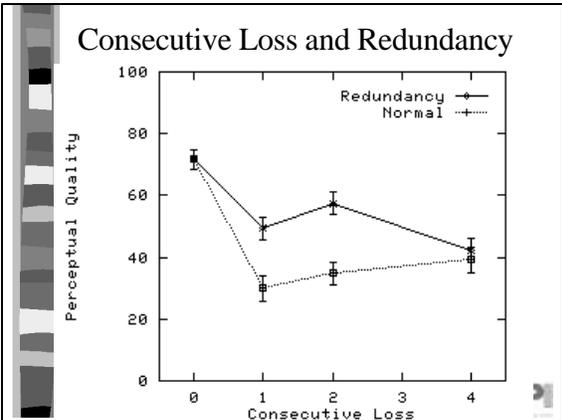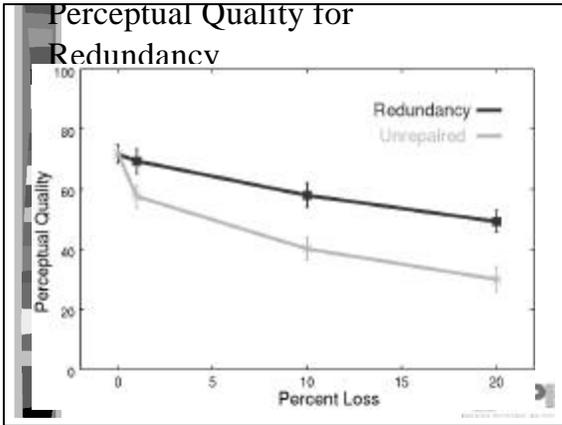
User Study for Interleaving

- Parameters to be tested
  - MPEG Quality 1 & 2
  - Loss Rate: no loss, 2%, 5%, 10%, 20%
  - Movie type: hockey game & CNN news
    + frequency of scene changes and
    + intensity of object actions
  - Distance Value: 2 & 5
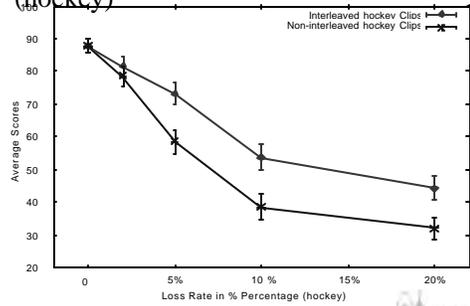- Totally 24 movie clips
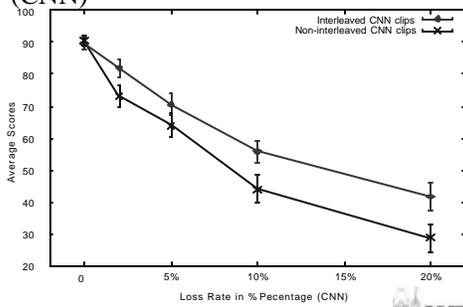 - 20 seconds / clips

User Study for Interleaving (II)

- Parameters not to be tested
  - Frame Rate: 30 frames/sec
  - Size of movie: 320 x 240 pixels
  - Hardware difference
    + All tests on one machine
    + One user each time
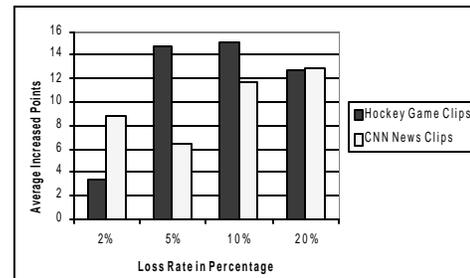 - Human interaction: one same assistant (me)

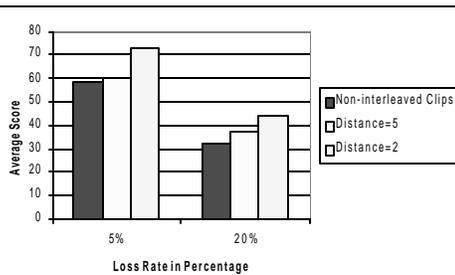WP

Perceptual Quality for Interleaving (hockey)

Interleaved hockey Clips
Non-interleaved hockey Clips

Average Scores

Loss Rate in % Percentage (hockey)

WP

Perceptual Quality for Interleaving (CNN)

Interleaved CNN clips
Non-interleaved CNN clips

Average Scores

Loss Rate in % Pecentage (CNN)

WP

Perceptual Quality for Interleaving – Movie Type

Average Increased Points

Hockey Game Clips
CNN News Clips

Loss Rate in Percentage

Perceptual Quality for Interleaving – Interleaving Distance

Average Score

Non-interleaved Clips
Distance=5
Distance=2

Loss Rate in Percentage

Perceptual Quality vs. MPEG Quality


Average Score

quality number 1
quality number 2

Loss Rate in Percentage (hockey)
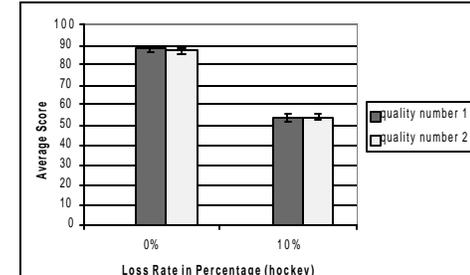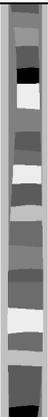
Conclusions

- Video Repair and Interleaving
  - Improves perceptual quality by 25% – 70%
  - Completely repairs video in the presence of single packet loss
- Bandwidth Overhead
  - About 10%
  - Can be decreased at cost of MPEG quality
- Movie Type
  - Not statistically significant for quality or overhead
- Effects of Increasing Distance Value
  - Observed to be non-beneficial
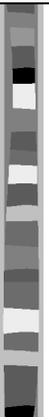
Future Work

- Frame-Packet Ratio
  - In our implementation = 1
  - >1 or <1?
- Other Compression Standards
  - MPEG-2, MPEG-4, Motion-JPEG
- Combine repair techniques
  - Interleaving + Redundancy
- Adaptive repair
- Effects of overhead on network congestion
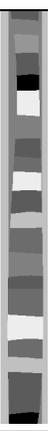
Evaluation of Science?

- Category of Paper
- Science Evaluation (1-10)?
- Space devoted to Experiments?