SALIENCY-COGNIZANT ERROR CONCEALMENT IN LOSS-CORRUPTED STREAMING VIDEO

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The Idea

**Goal:** Reconstruct a missing block $b$ lost during video streaming such that some fitting error cost function is minimized:

$$\min_b \text{fit}_\text{err}(b)$$

**Problem:** The problem is **under-determined**.

**Solution:** Add a **saliency term** as follows:

$$\min_b \{\text{fit}_\text{err}(b) + \lambda \text{saliency}(b)\}$$

**Advantages:**

1. Potential wrong candidates become **less attention-grabbing**.
2. It serves as a **true prior** in an ROI-based streaming application.
Loss Resilient Video Streaming

Region-Of-Interest-based Video Streaming

Protect Salient Regions
More!

High Salient
Low Salient
Original Frame
Encoder

Lossy Channel

High Salient
Received Frame
Decoder

Potential Missing Blocks

RECAP: Receiver Error Concealment using Acknowledge Preview (Thumbnail)

Original Frame → Channel → Reference Frame

Encoder

Thumbnail

Received Frame → Decoder

Thumbnail

RECAP

How RECAP Works?

There are some candidate blocks whose MSE with respect to the thumbnail block is below a threshold.
The Itti Saliency Model

Frequency Analysis of the Itti Model

The Effective Frequency Range Used by the Itti Model

\[ \left[ \frac{\pi}{256} - \frac{\pi}{16} \right] \]

The Proposed Method

We implement our proposed method within a **ROI-based video streaming framework**. We use **RECAP** as our error concealment method.

**Problem:** Which candidate block should we take?

**Solution:** Take the one that has lower saliency!
**The Proposed Method**

Yet a better solution: First, apply some filters on a bunch of candidates to reduce their saliency as much as possible, then select the one that has a lower saliency.

$$
\min_b \{ \text{fit}_\text{err}(b) + \lambda \text{saliency}(b) \}
$$

MSE between $b$ and thumbnail.
The Proposed Method

- Iteratively apply a Saliency Reduction Operator.
- Each time make sure that the solution is in good match with the thumbnail block.
Matching to Thumbnail

RECAP Candidate Block → H1(z) ↓ 2 → H1(z) ↓ 2 → Project To Thumbnail Operator → Thumbnail Block

H0(z) ↓ 2 → H0(z) ↓ 2

→ H0(z) ↓ 2

→ H0(z) ↓ 2

→ H0(z) ↓ 2

→ G0(z)↑ 2 → G0(z)↑ 2 → Modified RECAP Candidate Block

→ G1(z)↑ 2 → G1(z)↑ 2

→ G1(z)↑ 2

→ G1(z)↑ 2

→ G1(z)↑ 2

→ G1(z)↑ 2

→ G1(z)↑ 2

How projection to thumbnail works?

The Reconstruction Level

Quantization bin of the i-th DCT coefficient of the Thumbnail Block

The i-th DCT coefficient of the Candidate Block
Saliency Reduction Operators

We propose 4 saliency reduction operators:

1. Deblocking Filter
2. Notch Filter
3. Frequency Outlier Filter
4. Attention-Guiding Method
Deblocking Filter

Deblocking reduces saliency!

Before Deblocking

After Deblocking

Notch Filter

Frequency Outlier Filter

Clip the DCT coefficients of the central block based on the DCT coefficients of the neighboring blocks.

Attention-Guiding Method

Modify RGB values so that the region of interest becomes more/less salient.

\[
\alpha_{pq}^* = \alpha_{pq} + w_{pq} V_{\alpha_{pq}}
\]

- New RGB value
- Old RGB value
- A Weight Factor
- A factor that reflects how much a feature influences the saliency of the pixel

We replace this by a negative sign to reduce saliency instead.

A Block-Diagram of the Proposed Method

RECAP Candidate Block

Matching to Thumbnail

Saliency Reduction Operator

Final Low-Saliency Concealed Block

Lowpass Filter \( H_2(z) \)

Lowpass Filter \( H_1(z) \)

Lowpass Filter

Saliency Check

Project To Thumbnail Operator

Thumbnail Block

\( F_1(z) \rightharpoonup 2 \)

\( F_0(z) \rightharpoonup 2 \)

\( F_0(z) \rightharpoonup 2 \)

\( F_1(z) \rightharpoonup 2 \)

\( G_0(z) \rightharpoonup 2 \)

\( G_1(z) \rightharpoonup 2 \)

\( G_1(z) \rightharpoonup 2 \)

\( G_0(z) \rightharpoonup 2 \)
Subjective Tests

17 people

2AFC Experiment

2AFC: Two Alternative Forced Choice

Presentation Time

Response Time

10 sec

5 sec
Subjective Tests

Comparing the proposed method with the RECAP method based on the subjective results at 5 different average loss rates.

<table>
<thead>
<tr>
<th>Loss Rate</th>
<th>Method</th>
<th>Bus</th>
<th>Crew</th>
<th>Football</th>
<th>Stefan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RECAP</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Proposed Method</td>
<td>27</td>
<td>30</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>P-value</td>
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<td>0.0001</td>
<td>0.0061</td>
<td>0.0164</td>
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<tr>
<td>2%</td>
<td>RECAP</td>
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<td>3</td>
<td>7</td>
<td>9</td>
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<td></td>
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<td>30</td>
<td>31</td>
<td>27</td>
<td>25</td>
</tr>
<tr>
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<td>0.0001</td>
<td>0.0006</td>
<td>0.0061</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>RECAP</td>
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<td>3</td>
<td>10</td>
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<td></td>
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<td>24</td>
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<tr>
<td>P-value</td>
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<td>0.0001</td>
<td>0.0164</td>
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<tr>
<td>10%</td>
<td>RECAP</td>
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<td>8</td>
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<td>20%</td>
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<td></td>
</tr>
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</table>
Quantitative Results

Where does this PSNR gain come from?

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<thead>
<tr>
<th></th>
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<th>Football</th>
<th>Stefan</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSNR Gain ($d = 10$)</td>
<td>1.2 dB</td>
<td>3.2 dB</td>
<td>1.8 dB</td>
<td>0.9 dB</td>
</tr>
<tr>
<td>PSNR Gain ($d = 5$)</td>
<td>0.9 dB</td>
<td>2.8 dB</td>
<td>1.5 dB</td>
<td>0.6 dB</td>
</tr>
<tr>
<td>Saliency Reduction</td>
<td>10%</td>
<td>19%</td>
<td>12%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Our saliency prior helps us to find the right candidate.
Sample Results

bit rate=700kbps, loss Rate =10%

Proposed Method

RECAP Method
Conclusions

1. We introduced the concept of low-saliency prior for error concealment in a ROI-based video streaming application.

2. Low-saliency prior can increase the PSNR of reconstructed regions.

3. Reconstructed regions becomes less attention-grabbing.

\[
\min_b \{ \text{fit}_\text{err}(b) + \lambda \text{saliency}(b) \}
\]
Thank You!
Any Question?

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Supplementary Slides
Frequency Range

\[
\left[ \frac{\pi}{4} - \frac{\pi}{2} \right] \xrightarrow{\downarrow 2} \left[ 0 - \frac{\pi}{2} \right] \xrightarrow{\downarrow 2} \left[ 0 - \frac{\pi}{4} \right]
\]

\[
\left[ 0 - \pi \right]
\]
Subjective Tests

- Number of Participants: 17
- A two-sided **chi-square test** was used to examine the statistical significance of the results.
  - Risk Level: 95% (**p-value = 0.05**)
  - Null-hypothesis: the two methods are the same.

<table>
<thead>
<tr>
<th>Video</th>
<th>RECAP</th>
<th>Proposed</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>7 votes</td>
<td>27 votes</td>
<td>0.006</td>
</tr>
</tbody>
</table>
Notch Filter

Lowpass Filter $H_1(z)$

Lowpass Filter $H_2(z)$

Input Block

Output Block

Diagram showing the flow of signals through the notch filter system.
Adaptive Window for Saliency Computation

![Diagram of adaptive window with different block states: Missing Block, Available Block, Reconstructed Block]