WAVELET VIDEO COMPRESSION AND COMMUNICATIONS

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MEng.

A mini thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy at the University of Southampton

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Outline

- Motivation
- Overview of Mini-thesis
- Conclusions and Future Work
Motivation

- Over the last decades, there has been an increasing demand for multimedia communications. With the integration of wireless technologies and multimedia services, transmitting high quality images and video has become one of the main objectives for next generations (4G) mobile network systems.

- This mini-thesis explores the feasibility of providing video services for mobile users.

- The Dirac wavelet video codec, proposed by the BBC Research and Development Department, is capable of efficiently compressing video and yet achieving a high reconstructed video quality at a low bit-rate. Hence, in this mini-thesis we focus our attention on the design of wireless video communication systems using Dirac codec as a source codec.

- Although this work concentrates on the error resilient transmission of video, the principles, methodologies and algorithms proposed in this mini-thesis are applicable to other forms of multimedia content such as image data.
Overview of Mini-thesis

- Chapter 1: Introduction.
- Chapter 2: Wavelet-Based Video Codec.
- Chapter 3: Bit Sensitivity Study and Unequal Error Protection Applied to Dirac Video-Coded sequence.
- Chapter 4: Iterative Source-Channel Decoding for Reliable Dirac Video Communication.
- Chapter 5: Summary and Future Research Directions.
Chapter 1: Introduction

- Research Motivations
- Related Background (Overview of Video Coding, Video Communication)
- Organisation of Thesis
Chapter 2: Wavelet-Based Video Codec

- Introduction.
- Overview of Wavelet Video Codec.
- Specific Video Coding Techniques.
- Video Quality and Effective of Coding Parameters.
- Chapter Conclusions.
Chapter 3: Bit Sensitivity Study and Unequal Error Protection Applied to Dirac Video-Coded sequence.

- Introduction.
- Dirac video-coded sequence.
- Bit sensitivity study.
- Unequal error protection scheme for dirac video transmission.
- Chapter conclusions and future work.
Publication for this chapter:


Figure 1: Average PSNR degradation due to the bit corruption events for the "Miss America" QCIF video sequence encoded at 30 frame/s using intra-frame mode.
Figure 2: The relative frequency of occurrence for the various Dirac video bit partitions generated from the "Miss America" QCIF video sequence encoded at 30 frame/s \((MSB: \) the Most Significant Bit, \(VSB: \) Very Significant Bit, \(LSB: \) the Least Significant Bit).
Table 1: The average ratio of the three video partitions in the Dirac video sequence.

<table>
<thead>
<tr>
<th>Probability (%)</th>
<th>MSB portion</th>
<th>VSB portion</th>
<th>LSB portion</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.41</td>
<td>19.77</td>
<td>49.82</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: The coderate and the weight of the IRCCs.

<table>
<thead>
<tr>
<th>Subcodes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>coderate</td>
<td>0.35</td>
<td>0.45</td>
<td>0.5</td>
<td>0.55</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>weight(%)</td>
<td>34%</td>
<td>1.3%</td>
<td>4.8%</td>
<td>22%</td>
<td>6.5%</td>
<td>31%</td>
</tr>
</tbody>
</table>
Figure 3: The EXIT function of a rate-1/2 IRCC and that of its subcodes
Figure 4: EXIT charts of the channel equalizer, of the rate-1/2 NSC code and of the rate-1/2 IRCC when communicating over the 5-path ISI channel having impulse response of $h[n] = 0.227\delta[n] + 0.46\delta[n - 1] + 0.688\delta[n - 2] + 0.46\delta[n - 3] + 0.227\delta[n - 4]$
UEP System Model

- Video Encoder
- Data partitioning
- Data packetization
- IRCC Encoder
- Precoder
- Iterative decoding
- Video Decoder
- Unite data
- Data depacketization
- IRCC Decoder
- Map Equalizer
- Iterative decoding

n (ISI)
Figure 5: Comparison of the achievable video PSNR using both EEP and UEP.
Chapter 4: Iterative Source-Channel Decoding for Reliable Dirac Video Communication

- Introduction.
- Iterative Source-Channel Decoding Using the Dirac Video Codec.
- Overcomplete Mapping-Assisted Iterative Source-Channel Decoding.
- Chapter conclusions.

Iterative Source and Channel Decoding Model

Video Encoder $x_k \xrightarrow{\Pi} \bar{x}_k \xrightarrow{\Pi-1} y_k \xrightarrow{+} \hat{y}_k \xrightarrow{\Pi} \tilde{x}_k \xrightarrow{\Pi-1} L_e(x_k) \xrightarrow{\Pi-1} L_a(x_k) \rightarrow \text{Iterative Decoding} \rightarrow \hat{x}_k \rightarrow \text{Video Decoder}$

GLDPC Encoder $x_k \rightarrow y_k \rightarrow y_k \rightarrow \hat{y}_k \rightarrow \tilde{x}_k \rightarrow \text{Softbit Source Decoder}$
Table 3: The relative frequency of the 3-bit source symbol modelling the Probability Density Function (PDF) of the Dirac video-encoded bitstream extracted from our simulations.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Probability</th>
<th>Symbol</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0.2097020</td>
<td>100</td>
<td>0.1268470</td>
</tr>
<tr>
<td>001</td>
<td>0.0960067</td>
<td>101</td>
<td>0.0903356</td>
</tr>
<tr>
<td>010</td>
<td>0.0854893</td>
<td>110</td>
<td>0.0857518</td>
</tr>
<tr>
<td>011</td>
<td>0.1193480</td>
<td>111</td>
<td>0.1865200</td>
</tr>
</tbody>
</table>
Table 4: The parameters of the ISCD videophone scheme

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Video codec</td>
<td>Dirac</td>
</tr>
<tr>
<td>Bit-Interleaver Π₁</td>
<td>2280 bits</td>
</tr>
<tr>
<td>GLDPC component codes</td>
<td>BCH(6,8,1)</td>
</tr>
<tr>
<td>Component code rate of GLDPC</td>
<td>$r = \frac{6}{8}$</td>
</tr>
<tr>
<td>Code rate of GLDPC</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>Number of inner GLDPC iterations</td>
<td>3</td>
</tr>
<tr>
<td>Number of iterations</td>
<td>2</td>
</tr>
<tr>
<td>Modulation</td>
<td>BPSK</td>
</tr>
</tbody>
</table>
Figure 6: EXIT characteristics of the ISCD scheme designed for Dirac video transmission over the uncorrelated Rayleigh fading channel. The distribution of the source-encoded bitstream is presented in Table 3 using $M=3$ bits/symbol.
Figure 7: Overcomplete mapping-assisted iterative source-channel decoding
Table 5: source symbol mapping used in the simulations.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Mapping 0</th>
<th>Mapping 1</th>
<th>Mapping 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>000</td>
<td>1000</td>
<td>0000</td>
</tr>
<tr>
<td>001</td>
<td>001</td>
<td>1001</td>
<td>1001</td>
</tr>
<tr>
<td>010</td>
<td>010</td>
<td>1010</td>
<td>1010</td>
</tr>
<tr>
<td>011</td>
<td>011</td>
<td>1011</td>
<td>0011</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>0100</td>
<td>1100</td>
</tr>
<tr>
<td>101</td>
<td>101</td>
<td>0101</td>
<td>0101</td>
</tr>
<tr>
<td>110</td>
<td>110</td>
<td>0110</td>
<td>0110</td>
</tr>
<tr>
<td>111</td>
<td>111</td>
<td>0111</td>
<td>1111</td>
</tr>
</tbody>
</table>
Figure 8: The *extrinsic* information transfer characteristics of the over-complete mapping-assisted softbit-source decoder. The mappings are detailed in Table 5.
The prefix-bit selection algorithm;

**Input:** $M$, $Start\_bit$;

**Output:** A binary sequence $u = \{u_0, \ldots, u_{2^M - 1}\}$;

**Step 1:** $Start = 0$, $Stop = 2^M - 1$, $u_{Start} = Start\_bit$;

**Step 2:** For the set $[Start, Stop, u_{Start}]$ do

{ 

**Step 3:** Set $Mid = \frac{Stop - Start + 1}{2}$, $u_{Mid} = \overline{u_{Start}}$

where $\overline{u_{Start}}$ is the complement of a binary value $u_{Start}$

**Step 4:** if $(Start = Stop)$ then goto **Step 7**;

**Step 5:** Repeat **Step 2** for the set $[Start, Mid - 1, u_{Start}]$;

**Step 6:** Repeat **Step 2** for the set $[Mid, Stop, u_{Mid}]$;

} 

**Step 7:** Stop.
Figure 9: EXIT characteristics of systems designed for transmission over the uncorrelated Rayleigh fading channel.
Figure 10: BER performance of the System 1 and System 3 designed for transmission over the uncorrelated Rayleigh fading channel.
Figure 11: BER performance of the System 2 and System 3 designed for transmission over the uncorrelated Rayleigh fading channel.
Figure 12: Comparison of the achievable video PSNR using the above systems.
Chapter 5: Summary and Future Research Directions

- Summary.
- Future Research Directions.
Future Research Directions

for the over-complete mapping-aided softbit source decoding scheme we will carry out the following investigations:

1. Computational complexity analysis for the rate-$\frac{M}{M+L}$ over-complete mapping-aided softbit source decoding in comparison with the conventional $M$-bit source symbol softbit source decoding.

2. Fully characterize the performance of over-complete mapping-aided softbit source decoding scheme by investigating: Gain versus mapping rate and gain versus total delay.

3. Investigate the EXIT chart matching to facilitate the use of a suite of component over-mappings having the same coding rate.

4. Provide a list codebooks, which are EXIT optimized for different rate over-complete mappings.
Future Research Directions (Continued)

- Expand the application of the ISCD technique employing over-complete mapping-aided softbit source decoding, particularly to other video and audio codecs, such as for example the H.264 video coding standard and AMR audio codec, in the light of exemplifying a wide range of applications of the over-complete mapping scheme.

- Design a suitable Irregular Over-Complete Mapping for Wavelet Coded Wireless Video Telephony Using Iterative Source and Channel Decoding.

- Optimize coding rate allocation for UEP.
Thank You!