Joint Source-Channel Decoding of JPEG Images using Error Resilient Source Codes

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Abstract — **Iterative decoding of JPEG images does not perform well due to the poor distance property of the original JPEG Huffman codes. We propose a symmetric RVLC with large free distance which can dramatically improve the system performance when iterative decoding is performed. Simulation results indicate up to 4 dB coding gain is achievable.**

There is a significant body of literature (see references in [1]) that investigates iterative source-channel decoding for variable-length coded sources that achieve superior performance compared to separate source-channel coding. In this paper, we studied iterative source-channel decoding applied to JPEG coded images. We show that after increasing slightly the redundancy for the JPEG source codes, the system performance can be dramatically improved when iterative source-channel decoding is performed.

For a variable-length coded sequence, the symbol or codeword probabilities are usually assumed to be known. The state transition probabilities (STPs) [1] can be considered as source *a priori* information based on the bit-level trellis representation of variable length codes. The advantage of STPs is that they can be naturally incorporated into the maximum *a posteriori* (MAP) algorithm to improve system performance.

For an AWGN channel with zero mean and variance σ^2, the branch metric $\delta_k^{i,m,m'}$ can be expressed as

$$\begin{aligned}\delta_k^{i,m,m'} &= Pr(d_k = i, S_{k+1} = m', r_k | S_k = m) \\ &= \chi_k \exp(L_c r_k i) Pr(S_{k+1} = m', d_k = i | S_k = m), \quad (1)\end{aligned}$$

where χ_k is a constant and $L_c = 2/\sigma^2$. The last term in (1) is the STP which can be obtained from a VLC-trellis. Refer to [1] for more detailed information.

We examine a joint source-channel codec architecture. The transmitter consists of a source encoder serially concatenated with a recursive systematic convolutional (RSC) channel encoder. The receiver implements iterative decoding between the source APP decoder and the channel decoder. They are separated by a pseudo-random interleaver.

The JPEG still image compression standard has proved to be a success story in source coding techniques. For a gray JPEG coded image, there are two Huffman code tables. There is a 12-entry Huffman table for the DC luminance component, while there is a 162-entry Huffman table for the AC luminance components [2]. The original JPEG Huffman codes do not give good performance since they have free distance, d_f, of one. Due the their poor distance property, the convergence behaviour of JPEG Huffman codes, which is important for iterative source-channel decoding, is poor. By training "Lena" and "Goldhill" images, we obtained the probability distribution for DC symbols, which has an average codeword length of 2.6790. Based on the existing JPEG Huffman code for the luminance DC component $\mathcal{C}_H$, we proposed an error-resilient symmetric reversible variable-length code (RVLC) $\mathcal{C}_R$ which has an average codeword length of 2.9857 and $d_f \geq 2$ [1].

We transmitted 2000 differential pulse code modulation (DPCM) coded DC symbols from the "Lena" 256 × 256 image over the AWGN channel. The coded bitstream out of the JPEG DC DPCM encoder was protected by a 16-state inner code with code polynomials 35/23 in octal notation. The channel coding rate for the coded bitstream using the Huffman code $\mathcal{C}_H$ was 1/2. The interleaver sizes for $\mathcal{C}_H$ and $\mathcal{C}_R$ are 5335 and 5899, respectively. A 4 dB coding gain is observed in simulations as shown in Fig. 1 after taking the increased average codeword length for $\mathcal{C}_R$ into consideration.

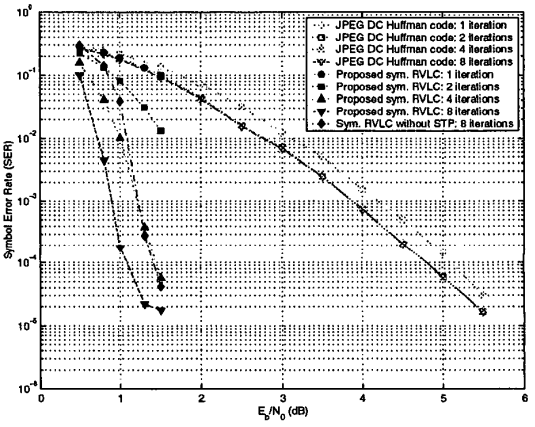

Figure 1: Simulation results for iterative decoding using Huffman code $\mathcal{C}_H$ and proposed symmetric RVLC $\mathcal{C}_R$.

Acknowledgments

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References

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