

Iterative Decoder Design for Joint Source-Channel LDPC Coding

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Abstract — We consider joint source-channel coding with variable length codes (VLCs) and LDPC codes. We propose an iterative source-channel decoding system, which involves message passing between a soft-input-soft-output VLC decoder and an LDPC decoder. The proposed system utilizes the residual redundancy of the variable length code during the iterative decoding process, and is expected to exhibit decoding convergence at a lower SNR relative to the system in which source and channel decoding are performed separately. We present computer simulation results that confirm the expected gain of the proposed system.

Keywords — joint source-channel coding, LDPC codes, variable length codes

I. INTRODUCTION

STANDARD communication systems typically involve separate source and channel encoding and decoding. This is justified by the Shannon's separation theorem, which states that the two-stage system can approach optimum performance bounds as closely as desired, provided that both codes are allowed sufficiently large lengths. In practical systems, however, the code design is constrained in terms of complexity or delay. Practical source and channel codes are consequently suboptimal, and their performance can be improved by utilizing joint source-channel coding.

Since variable length source codes are applied in many data compression standards, extensive work has been done in the previous years to construct joint source-channel decoders that exploit the suboptimality of these codes. Early research in this area considered non-iterative decoding with Huffman codes and convolutional codes (CCs) [1]-[3]. More recently, Bauer and Hagenauer [4] introduced an iterative source-channel decoding system, which involves reversible variable length codes (RVLCs) [5] in combination with convolutional codes. As shown in [4], iterative decoding with soft-input-soft-output RVLC and CC decoders yields superior results at a low SNR, compared to non-iterative source-channel decoding.

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Additional improvements can be obtained by optimized VLC design, as presented in [6].

Iterative decoding systems for Huffman coded Markov sources in combination with convolutional codes were proposed in [7-8]. While Kliewer and Thobaben [8] proposed a system that utilizes soft-input-soft-output (SISO) constituent decoders similar to the decoders in [4], Guyader *et al.* [7] introduced a Bayesian-network based decoding system. Both [7] and [8] reported substantial gains associated with iterative decoding, while further improvements were presented in [9-10]. The application of iterative source-channel decoding in image communication systems was considered in [11-13].

In [14-15], we considered joint-source channel coding with variable length codes (VLCs) and turbo codes, and proposed iterative VLC-turbo decoders that simultaneously exploit the residual redundancy of VLCs and the good convergence properties of turbo codes. We showed that VLC-turbo decoders significantly outperform VLC-CC decoders, and that they perform very close to the theoretical limit. Further analysis on VLC-turbo systems can be found in [16-17].

Low-density parity-check (LDPC) codes, introduced by Gallager in 1960s, have recently regained attention [18-19] as the capacity-approaching channel coding alternative to turbo codes. Consequently, joint source-channel coding with LDPC codes represents an interesting alternative to joint source-channel turbo coding. In this paper we consider variable length codes in combination with LDPC codes. We propose an iterative joint source-channel decoding system, which involves a soft-input-soft-output VLC decoder in combination with an LDPC decoder. We compare the performance of this system to the system that involves separate VLC-LDPC decoding. Additionally, we discuss VLC-LDPC coding relative to VLC-turbo coding.

II. ITERATIVE SOURCE-CHANNEL DECODING WITH VLCs AND LDPC CODES

The considered system is shown in Fig. 1. Let $\underline{u}=(u_1, \dots, u_J)$ denote a sequence of J symbols at the output of an M -ary i.i.d. information source, with probability mass function $p_U=\{p^1, \dots, p^M\}$. This sequence is first encoded by a variable length code into a binary sequence $\underline{w}=(w_1, \dots, w_K)$, which is further encoded for error-protection into $\underline{x}=(x_1, \dots, x_N)$, and transmitted through a communication channel.

