Iterative Symbol Decoding of Variable-Length Codes with Convolutional Codes

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Abstract: **In this paper, we present a symbol-level iterative source-channel decoding (ISCD) algorithm for reliable transmission of variable-length codes (VLCs). Firstly, an improved source a posteriori probability (APP) decoding approach is proposed for packetized variable-length encoded Markov sources. Also proposed is a recursive implementation based on a three-dimensional joint trellis for symbol decoding of binary convolutional codes. APP channel decoding on this joint trellis is realized by modification of the Bahl-Cocke-Jelinek-Raviv algorithm and adaptation to the non-stationary VLC trellis. Simulation results indicate that the proposed ISCD scheme allows to exchange between its constituent decoders the symbol-level extrinsic information and achieves high robustness against channel noises.**

Index Terms: **Extrinsic information, iterative source-channel decoding (ISCD), three-dimensional joint trellis, variable-length code (VLC).**

I. INTRODUCTION

THE existing audio and video coding standards adopt some form of variable-length codes (VLCs) for increasing the source compression performance. While in the absence of transmission errors, the VLC sequence can easily be decoded by parsing the bitstream, the decoding of corrupted VLC sequences is rather difficult due to a possible loss of synchronization between bit and symbol time. This has motivated investigation into trying to design a reliable transmission system with increased robustness to channel errors. We can generally assume that there is a certain amount of residual redundancy remaining in the VLC sequence due to delay and complexity constraints for the quantization stage. Such residual redundancy appears on the symbol-level, either in terms of a non-uniform probability distribution or in terms of time-correlation between consecutive source indexes. Many authors have proposed trellis-based decoding algorithms for decoding of VLC data based on residual source redundancy [1]–[6]. The algorithms can be classified into two ways, according to the source they are designed and according to the VLC trellis representation they need to perform decoding. While previous work only considered uncorrelated sources [1]–[4], the methods in [5] and [6] assume a first-order Markov source model and exploit the residual source index correlation in the VLC source decoding process. In [1], [2], and [6], a bit-level VLC trellis representation is derived and is applied in conjunction with the Bahl-Cocke-Jelinek-Raviv (BCJR) algorithm [7] to provide the *a posteriori* probability (APP) of the decoded bits. On the other hand, APP source decoding on a symbol-level VLC trellis is proposed in [3] and [4] for memoryless sources, and is extended to first-order Markov sources in [5]. In the symbol-level VLC trellis, each branch represents a possible variable-length codeword in the VLC sequence and each state represents a hypothesis for the actual bit position in the encoded bit sequence. In this paper we propose an improved APP decoding algorithm for VLC-encoded Markov sources, which can be regarded as a generalization of the approach in [5]. Both algorithms are realized on the symbol-level VLC trellis, differing mainly in the factorization of the index-based APPs. In [5], different branch metrics were derived in forward and backward recursions and only the source index probability distribution corresponding to a zeroth-order Markov model was considered in the backward recursion. As a new result, we show that by modification of the BCJR algorithm the source index correlation can be utilized as *a priori* information in both forward and backward recursions.

When the VLC sequence is additionally protected by channel codes [8], the entire system can be viewed as having the residual source redundancy as implicit outer channel codes that are serially concatenated with the explicit inner channel codes. Viewed from this perspective, the iterative source-channel decoding (ISCD) techniques [9] inspired by the turbo principle have been shown to be effective by using the residual source redundancy and assisted with the reliability information provided by the soft-in soft-out (SISO) channel decoder. With respect to an implementation of VLC-based ISCD, all of the channel decoders in [2]–[6] have in common that they consider a bit-level convolutional trellis representation rather than decoding each VLC codeword on a symbol-by-symbol basis. This is justified by the fact that in many practical systems binary convolutional codes are utilized, so SISO channel decoding can be implemented efficiently by the BCJR algorithm [7]. However, it has to be emphasized that the major part of the iterative process runs on bit-level, but the VLC source decoder itself is realized on symbol-level. This causes the problem that only bitwise source *a priori* knowledge can be exploited by the channel decoder, since the classical BCJR algorithm is derived based on a bit-level code trellis. The best way to combine the source *a priori* knowledge on symbol-level with the extrinsic information of the channel decoder on bit-level still needs to be found. A common approach is to perform the symbol-to-bit probability conversion in each passing of the extrinsic information between

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