Title	LDPC符号を復号化するために相互情報量を最大化するマッピング関数
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Abstract

Low-density parity-check (LDPC) codes have been reported to perform close to the channel capacity. LDPC decoders and channel quantization algorithms are usually implemented using floating point simulations in Matlab/C or another programming languages. Once these algorithms are carefully optimized, the next step is to carry out their corresponding hardware implementation in a very-large-scale integrated (VLSI) circuit. In such implementation, LDPC decoders and channel quantization algorithms are converted to a fixed-point representation. For example, the offset min-sum (OMS) algorithm for decoding LDPC codes uses real-valued operations: addition, min. But the channel and decoder messages are usually quantized to a bit width of 4 to 7 bits, depending on the performance/complexity tradeoff. In this research, floating-point algorithms are not used. Instead, the central method is "direct design" of VLSI circuits for LDPC decoders and channel quantizers.

The objective of this research is to design LDPC decoder schemes and channel quantizers that can be implemented in VLSI circuits. For LDPC decoders, the goal is designs that achieve high throughput (a few iterations) and low gate count (a few bits per message). For channel quantization, the goal is to find an optimal quantization scheme, for a fixed bit width, even when the error distribution model is based only on sample data.

In this dissertation, we have developed a technique where the LDPC decoders and channel quantization implementations, including quantization of messages, are designed using only the probability distribution from the channel. Given a probability distribution, our method designs a lookup table (LUT) that maximizes mutual information, and LUTs are implemented directly in VLSI circuits. This is the "max-LUT method".

The proposed lookup tables are sometimes referred as mapping functions. The mapping functions we propose are used for channel quantization and for message-passing decoding of LDPC codes. These mapping functions are not derived from belief-propagation decoding or one of its approximations, instead, the decoding mapping functions are based on a channel quantizer that maximizes mutual information. More precisely, the construction technique is a systematic method which uses an optimal quantizer at each step of density evolution to generate message-passing decoding mappings.

In a simple manner, the design of LDPC decoders by maximization of mutual information is analogous to finding non-uniform quantization schemes where the quantization can vary with each iteration.

The proposed decoding mapping functions are particularly well suited for data storage applications, because they can be designed from non-parametric and irregular noise distributions. Though finite-length simulations show that the proposed decoding mappings functions present good performance for a variety of code rates.

Numerical results show that using 4 bits per message and a few iterations (10–20 iterations) are sufficient to approach the error-rate decoding performance of full (without quantization) sum-product algorithm (SPA), less than 5–7 bits per message typically needed to perform around 1 dB away from the error-rate decoding performance of full SPA.

Another result of this research is that the construction technique for the mapping functions is flexible since it can generate maps for arbitrary number of bits per message, and can be applied to arbitrary binary-input memoryless channels.

Keywords: LDPC decoding, mapping functions, lookup tables, quantization, sum-product algorithm.