A Distortion Optimal Rate Allocation Algorithm for Transmission of Embedded Bitstreams over Noisy Channels

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Embedded bitstreams are generated by many source coders to allow the progressive reconstruction of the source at different bit rates from the prefixes of a single bitstream. In a packet transmission system, such bitstreams are packetized and transmitted over noisy channels. As part of packetization, an error correction coding scheme is often used to protect the packets against channel errors. It is well-known that the unequal error protection (UEP) of the packets usually results in a better end-to-end performance for the joint source-channel coding scheme compared to the less sophisticated equal error protection. Given a sequence of channel codes, the distortion-rate function of the source coder, and the channel conditions, the problem of assigning channel codes of different rates to different source packets under a constraint on the total bit budget or the total transmission rate is called rate allocation problem. Well-known cost functions for such an optimization problem are the average mean squared error (MSE) distortion, the average peak signal-to-noise-ratio (PSNR). We indiscriminately refer to the corresponding optimal solutions for these cost functions as distortion optimal.

There are two different approaches for packetizing the source output and constructing the transmitted packets. In the first approach, source packets all have the same length and thus the lengths of the packets after channel coding would be different. We refer to the corresponding rate allocation problem as variable-length packet problem (VPP). In the second approach, transmitted packets all have the same length and thus depending on the channel coding rate, source packets would have different lengths. This is referred to as fixed-length packet problem (FPP). The distinction between VPP and FPP is important as the proposed solutions to one problem may not be readily applicable to the other. In fact, while an efficient approach with quadratic complexity in total transmission rate for the globally distortion optimal solution of VPP is presented in [1], no fast globally distortion optimal solution is known for FPP.

In this paper, we propose a globally distortion optimal solution for FPP. Our method, which is applicable to any source with arbitrary distortion-rate characteristics, has quadratic complexity in $N$, where $N$ is the number of transmitted packets. It is based on constructing a search trellis in which trellis levels represent the number of packets, trellis states at a given level $i$ embody the possible source rates corresponding to $i$ packets, and edges represent different code rates. Such a trellis, starts from a single root state and spreads out in $N$ levels. We prove that the backward application of a Viterbi-like algorithm to this trellis starting from the final states and working towards the root results in a survivor path that provides us with the distortion optimal rate allocation solution. The proposed method can also be applied to VPP, providing an alternative to the algorithm of [1] with comparable complexity.

Reference