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Optimal Communication For Sources And Channels With Memory And Delay-Sensitive Applications

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Abstract

Shannon's theory of information was developed to address the fundamental problems of communication, such as the reliable data transmission over a noisy channel and the optimal data compression. During the years, it has expanded to find wide range of applications in many areas ranging from cryptography and cyber security to economics and genetics. Recent technological advances designate information theory as a promising and elegant tool to analyze and model information structures within living organisms. The key characteristics of data transmission within organisms are that they consider sources and channels with memory and feedback, they handle their information in a fascinating Shannon-optimum way, while the transmission of the data is delayless. Despite the extensive literature on memoryless sources and channels, the literature regarding sources and channels with memory is limited. Moreover, the optimality of communication schemes for these general sources and channels is completely unexplored. Optimality is often addressed via Joint Source Channel Coding (JSCC) and it is achieved if there exists an encoder-decoder scheme such that the Rate Distortion Function (RDF) of the source is equal to the capacity of the channel.

This work is motivated by neurobiological data transmission and aims to design and analyze optimal communication systems consisting of channels and sources with memory, within a delay-sensitive environment. To this aim, we calculate the capacity of the given channel with memory and match it to a Markovian source via an encoder-decoder scheme, utilizing concepts from information theory and stochastic control theory. The most striking result to emerge from this research is that optimal and delayless communication for sources and channels with memory is not only feasible, but also it is achieved with the minimum complexity and computational cost. Though the current research is stimulated by a neurobiological application, the proposed approach and methodology as well as the provided results deliver several noteworthy contributions to a plethora of applications. These, among others, include delay sensitive and real time communication systems, control-communication applications and sensor networks. It addresses issues such as causality, power efficiency, complexity and security, extends the current knowledge of channels and source with memory, while it contributes to the inconclusive debates of real time communication and uncoded data transmission.