DEPARTMENT OF ELECTRICAL ENGINEERING
PHD DISSERTATION DEFENSE

Theoretical Modeling and Practical Operation of Channels with Output Memory

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Abstract

In this work, we focus on a subclass of channels with memory, called "channels with output memory", in which the state of the channel is solely characterized by the previous output of the channel. This thesis contains two parts and covers modeling, signal processing and estimation problems in channels with output memory. In the first part, we model the multi-level per cell (MLC) flash channel, which has been widely used as the leading technology in non-volatile solid state drive (SSD) devices during the past decade, as a channel with output memory. We show that the state of an MLC flash channel at any given time depends only on the outputs of the neighboring cells due to the existing capacitance coupling effect.

Our results on MLC flash channels mainly stem from the signal processing techniques in which we provide an accurate model for MLC flash memory; using this model we find a mathematically tractable way to formulate the write process, and finally design the optimal detector for flash memory. The second part of our work concentrates on parameter estimation for specific types of channels with output memory, which we call ``Markov channels'', in which the channel input/output pairs form a Markov process. We emphasize at the outset that we do not exclude slow mixing of the channel evolution. We observe a length-n sample of the input/output pair sequence generated by applying a known i.i.d input process and obtaining its corresponding output from an unknown, stationary ergodic Markov channel over a finite alphabet. Using this sample, we want (i) a best approximation of the set of transition probabilities (ii) the stationary probabilities of an output string, and (iii) estimate or at least obtain heuristics of the information rate of the process. Combining the results of universal compression with the Aldous' coupling arguments, we obtain sufficient conditions on the length-n sample (even for slow mixing models) to identify when naive (i) estimates of the model parameters are accurate; (ii) estimates related to the stationary probabilities are accurate ; we also bound the deviations of the naive estimates from the true values.