The Application of Constrained Coding to Minimum Pearson Distance Detection in the Presence of Channel Mismatch

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Abstract - The performance of certain transmission and storage channels, such as optical recording and Non-Volatile Memory (Flash), is seriously hampered by the phenomena of unknown offset (drift) or gain. We will show that Minimum Pearson Distance (MPD) detection, unlike conventional Minimum Euclidean Distance detection, is immune to offset and/or gain mismatch. MPD is used in conjunction with $T$-constrained codes that consist of $q$-ary codewords, where in each codeword $T$ reference symbols appear at least once. We will analyze the redundancy of the new $q$-ary coding technique, and compute the error performance of MPD in the presence of additive noise. Implementation issues of MPD will be discussed, and results of simulations will be given.

I. INTRODUCTION

We consider a communication codebook, $S$, of chosen $q$-ary sequences $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ over the $q$-ary alphabet $Q = \{0, 1, \ldots, q-1\}$, $q \geq 2$, where $n$, the length of $\mathbf{x}$, is a positive integer. It is assumed that the received codeword $r = a(x + \nu) + b$, $r_i \in \mathbb{R}$, is scaled by an unknown factor, called gain, $a$, $a > 0$, offsetted by an unknown offset $b$ (both quantities unknown to both sender and receiver), where $a$ and $b \in \mathbb{R}$, and corrupted by additive noise $\nu = (\nu_1, \ldots, \nu_n)$, $\nu_i \in \mathbb{R}$. We use the shorthand notation $\mathbf{x} + \mathbf{b} = (x_1 + b, x_2 + b, \ldots, x_n + b)$.

An example of such a channel in practice is optical disc recording, where both the gain and offset depend on the reflective index of the disc surface and the dimensions of the written features [1]. Fingerprints on optical discs may result in rapid gain and offset variations of the retrieved signal. Reading errors in solid-state (Flash) memories may originate from low memory endurance, by which a cell drift of threshold levels in aging devices may cause programming and read errors [2]. It has been proposed to use a certain part of the memory cell array as reference cells (in the context of tele-communications, these are usually named training sequences). The reference cells are written with known signal levels, and are continuously monitored to obtain estimates of the momentary value of gain and offset [3].

In optical disc recording devices and non-volatile memories, constrained codes, specifically dc-free or balanced codes, have been used to counter the effects of offset and gain mismatch [4], [5]. Jiang et al. [2] addressed a $q$-ary coding technique, called rank modulation, for circumventing the difficulties with flash memories having aging offset levels. In rank modulation, each of the $q$ symbols appears once, so that $n = q$.

We will propose the Pearson distance as an alternative to the Euclidean distance, since it has the advantage that it is invariant (up to a sign) to changes in offset and scale of the received vector. The Pearson distance measure can only be applied to codebooks with special properties, and constrained coding is therefore required. We propose $q$-ary $T$-constrained codes, where $T, 0 < T \leq q$, preferred or reference symbols must appear at least once in every codeword [6]. The redundancy of the proposed $q$-ary $T$-constrained codes is much lower than that of the prior art $q$-ary balanced codes, which makes $T$-constrained codes more attractive for practical applications.

REFERENCES