A LEARNING VOLUME CONTROL THAT IS ROBUST TO USER INCONSISTENCY

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ABSTRACT

We describe a Learning Volume Control (LVC) algorithm that learns the volume control operations of a hearing aid user in such a way that the internal settings of the volume control will over time absorb the user's preferences. For practical use, the algorithm should be made robust against inconsistent behavior of the user. We propose two algorithms for LVC (based on LMS learning and Kalman filtering) and demonstrate desirable properties of our LVC in several simulations.

1. INTRODUCTION

Many electronic personal devices contain algorithm parameters that are preset to values that aim to optimally match the preferences and behavior of its user. To a certain extent, this can indeed be done in a fitting session, e.g. at a hearing aid dispenser. However, not every individual user preference can be put into the device in this manner: some particularities of the user may be hard to code/represent into the algorithm, his typical sound environments may be mismatched or changing, and also his preference patterns may be changing. Therefore one would like to *personalize* the instrument to the preferences of its user in on nn-line fashion, i.e. during usage in-the-field. The main idea of this paper is to absorb user adjustments to the volume control of a hearing aid in the parameters of the volume control algorithm. Ultimately, this strategy should lead to fewer user manipulations. Clearly, the learning algorithm should be robust to inconsistent user behavior.

Say here what's to come in the next sections.

2. SYSTEM DESCRIPTION

The situation is illustrated in Fig. 1. The amplitude of a signal x_t is adjusted by a gain g_t to yield $y_t = g_t x_t$. In a typical application, the gain g_t is controlled by an *automatic volume control* (AVC) module. The AVC unit takes as input u_t, which holds a vector of relevant features wrt the desired gain for signal x_t. For instance, u_t could hold short-term RMS and SNR estimates of x_t. In a linear AVC, the desired (log-domain) gain G_t is a linear function (with saturation) of the input features, i.e.

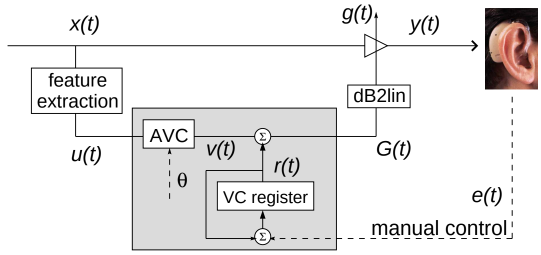

Figure 1: *Learning Volume Control (LVC) flow diagram*

$$G_t = \theta_{t-1}^T u_t + r_{t-1} \tag{1}$$

where the offset r_t is read from a volume-control (VC) register. (We work in discrete time steps, so subscript $t-1$ actually refers to $t - T_s$, where T_s is the sampling period). Sometimes, during operation of the device, the user is not satisfied with the volume of the received signal y_t. He is provided with the opportunity to manipulate the gain of the received signal by changing the contents of the VC register through turning a volume control wheel. We will let e_t represent the accumulated change in the VC register from $t-1$ to t as a result of user manipulation. Our learning goal is to slowly absorb the regular patterns in the VC register into our AVC model parameters θ. Ultimately we hope that this process will lead to a reduced number of user manipulations.

We will use an additive learning process,

$$\theta_t = \theta_{t-1} + \tilde{\theta}_t \tag{2}$$

where the amount of *parameter drift* $\tilde{\theta}_t$ is determined by specific choices for learning algorithms, such as LMS or Kalmin filtering. The learning update Eq.2 should not affect the actual gain G_t and hence we need to compensate by subtracting an amount $\tilde{\theta}_t^T u_t$ from the VC register. The VC register contents are thus described by

$$r_t = r_{t-1} - \tilde{\theta}_t^T u_t + e_t. \tag{3}$$