Variable Pre-emphasis LPC for Modeling Vocal Effort in the Singing Voice

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Introduction

People can perceive differences in vocal effort between voices, even when the pitch is the same and sound levels have been normalized. In this situation, the largest indicator of vocal effort is the amount of high-frequency content in the voice relative to low frequency content (Figure 1). The goal of this research is to use linear prediction coding to modify the perception of vocal effort.

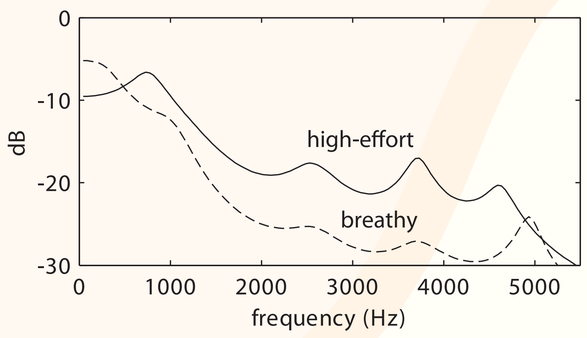

Figure 1: Frequency envelope of a high effort voice compared to a low effort (breathy) voice.

Linear production coding is a common voice analysis-synthesis technique that is based on a source-filter concept of voice production (Figure 2).

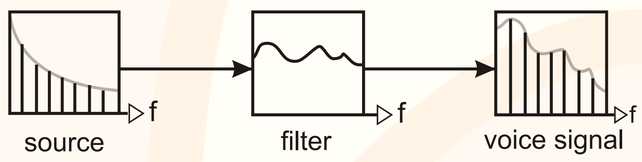

Figure 2: Source-filter concept of voice production

Problem

To manipulate vocal effort, we need a model that can capture and modify the spectral envelope of the glottal source. However, linear prediction coding, as it is often implemented, results in an estimated source that has a fixed spectral envelope (Figure 3 & 4). As a result, the LPC filter sounds like it has vocal effort [1]. Ideally, we want the perception of vocal effort to be controlled by the residual.

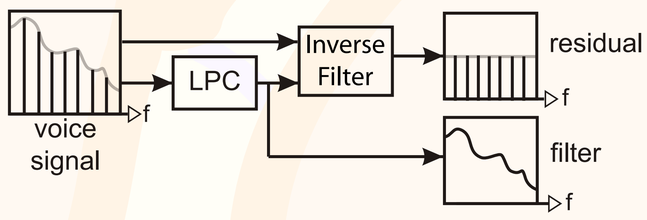

Figure 3: Basic LPC algorithm. The residual, which represents the glottal source, has a flat spectrum.

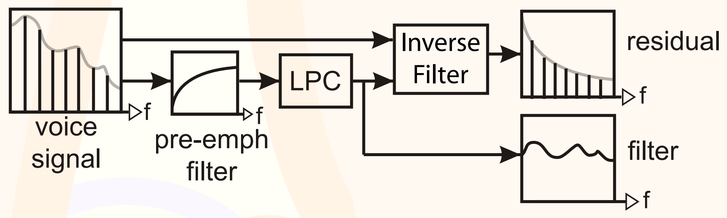

Figure 4: In voice applications, LPC typically involves a pre-emphasis filter. The spectral envelope of the residual has an inverse relationship to the pre-emphasis filter. When the pre-emphasis is fixed (as it often is) the residual is also fixed.

Method

Since the pre-emphasis filter controls the spectral envelope of the residual, we propose that variable pre-emphasis LPC (VPLPC) can model vocal effort. We replace the fixed pre-emphasis filter with low-order LPC and bandwidth expansion (BWE).

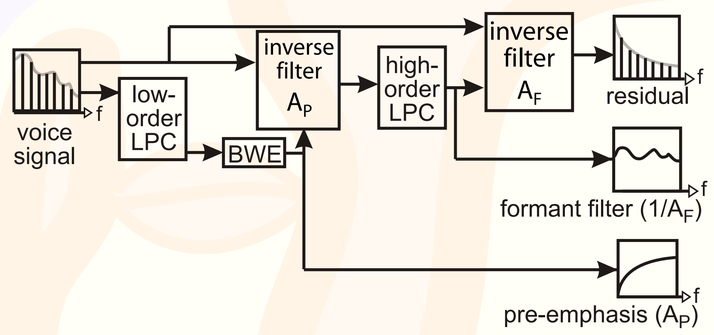

Figure 5: Variable pre-emphasis LPC (VPLPC) analysis.

Method cont'd

Low-order LPC estimates a variable pre-emphasis filter. The variable pre-emphasis filter captures the overall balance between high and low frequencies. Figure 6 shows pre-emphasis filters derived from high and low effort voices.

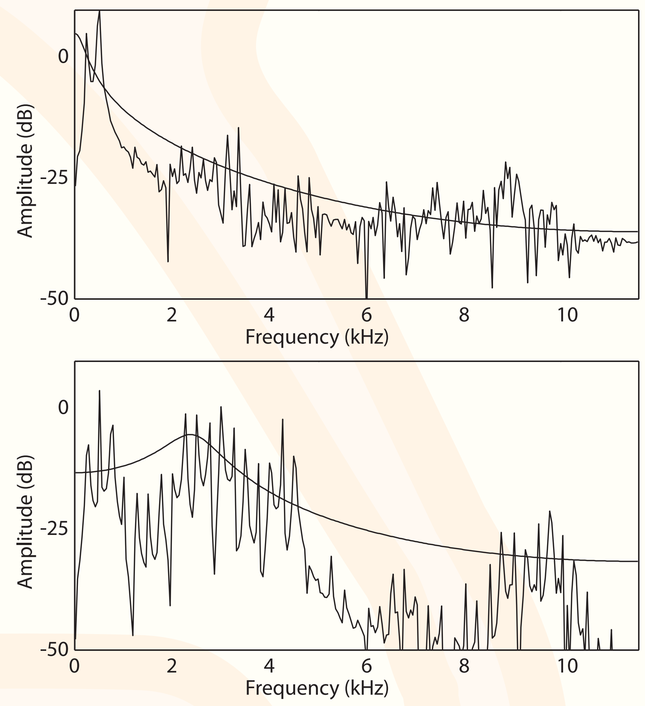

Figure 6: The pre-emphasis filter estimated by 3rd order LPC for a low-effort (breathy) voice (top) and a high-effort voice (bottom).

To change the perception of vocal effort, we modify the pre-emphasis and resynthesize the voice (Figure 7). The residual and the formant filter from the original voice remain unchanged. When appropriate, aspiration noise is used to simulate breathiness.

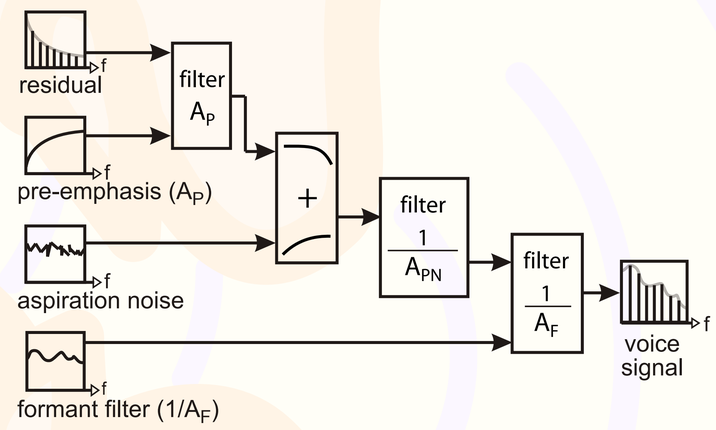

Figure 7: VPLPC synthesis.

Results

We attempted to remove vocal effort from high-effort voices by modifying the pre-emphasis and adding aspiration noise. The resulting voice sounded as though it had less effort but it was not fully transformed into a breathy voice. Sound excerpts are provided.

We attempted to add vocal effort to breathy voices by modifying the pre-emphasis. The resulting voice sounded as though it had more effort but noise from the original breathy voice was present. Sound excerpts are provided.

One of the advantages of VPLPC is that it should provide a formant filter (A_F) that is more consistent across varying voice qualities. We compared formant filters from standard LPC and VPLPC. The VPLPC formant filters sounded more consistent. Sound excerpts are provided.

Conclusion

Variable pre-emphasis partially transformed the perceived vocal effort by modifying the spectral envelope of the LPC residual. For a complete transformation of vocal effort, the mix of harmonics and noise in the residual must be appropriately modified. Future work will focus on improving the blending of aspiration noise, eliminating noise artifacts, and carrying out controlled listening experiments.

[1] KI Nordstrom, PF Driessen, and GA Rutledge, "Influence of the LPC filter upon the perception of breathiness and vocal effort", *IEEE Int. Symposium on Signal Processing and Information Technology,* Vancouver, BC, Canada, August 2006.