Virtual Bass System

Deep rich sound from small loudspeakers

The virtual bass system (VBS) enhances the poor bass performance of the small and flat-panel loudspeakers by tricking the human auditory system to perceive the low-frequency component, that is not physically reproduced. VBS is based on a psychoacoustic phenomenon known as the "missing fundamental", which states that higher harmonics of the fundamental frequency can produce the sensation of the fundamental frequency in the human brain. The output signal of the VBS consists of the generated higher harmonics and the original signal, so listeners can perceive the enhanced bass performance with loudspeakers having poor bass response.

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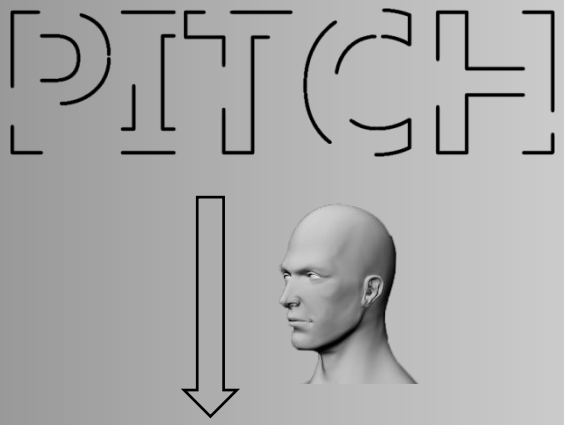
Deep rich sound from small speakers

Hao Mu and Woon-seng Gan



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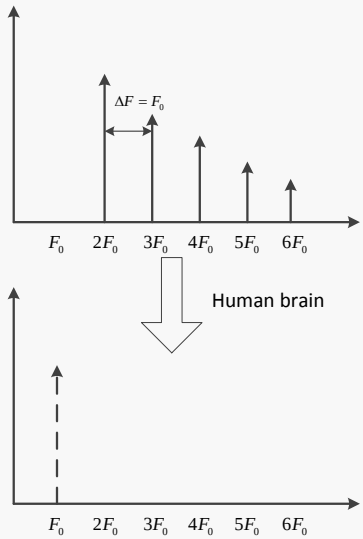
Missing Fundamental

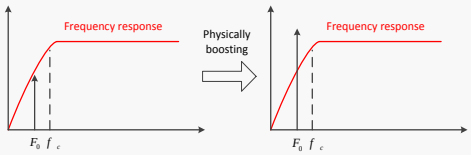
Human auditory system can reconstruct the fundamental frequency from the harmonics even if the fundamental frequency is missing.



Motivation

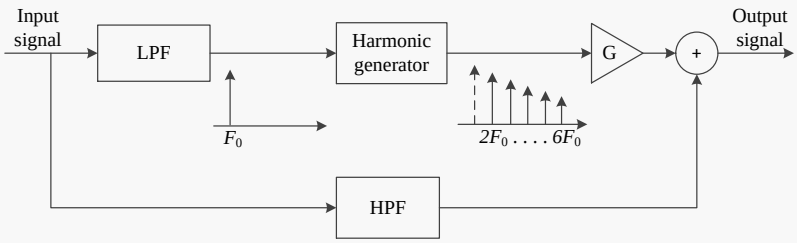
1. Poor bass performance of the small speakers in flat TV or hand-phone.

2. Physically boosting low frequencies potentially causes overload or even damage the speaker.



General Framework

Virtual bass system (VBS): generate higher harmonics and recombine them with the original signal to recreate bass effect psychoacoustically



LPF: low-pass filter, HPF: high-pass filter, G: gain for generated harmonics

Hybrid VBS

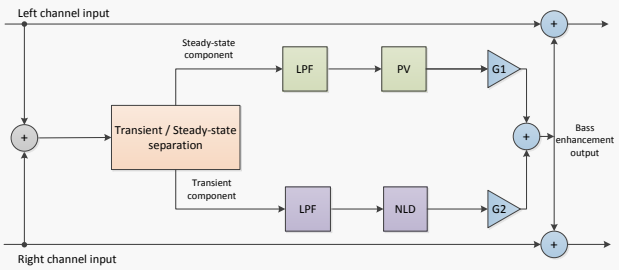
1. Nonlinear device (NLD): approximated by a polynomial expansion of function

$$y(n) = \sum_{i=0}^{N} h_i x^i(n)$$

Advantages: Impressive for transient components [1]
Disadvantages: 1) Poor performance for steady-state signal
2) No control over individual harmonics

2. Phase vocoder (PV): a short-time Fourier analysis and synthesis method
Advantages: 1) Suitable for steady-state signal
2) Precise control over individual harmonics
Disadvantages: Transient smearing [1]

3. Hybrid VBS: combining NLD and PV by separating signal into transient and steady-state components



Separation of input signal

1. Cascade combination of spectrogram masking and onset / offset detection method
2. Spectrogram masking
   1) Based on the fact that steady-state component appears as a horizontal ridge on the magnitude spectrogram, while the transient component forms a vertical ridge
   2) Using median-filter to generate spectrogram masking
3. Onset / offset detection
   1) Using high frequency content (HFC) function to detect onset / offset of transient component
   2) Small delay and suited for real-time application

Timbre Matching

Objective: increase the audio quality by adjusting timbre of harmonics similar to original sound source [2]
Theory: adjusting harmonic weighting in PV to match the spectral envelop of harmonics and original sound
Difficulty: interference effect for polyphonic music
Method: 1) grouping frequency bins into critical band
2) temporal averaging (based on the fact that bass source is different from the other sources)
Result: At the same bass intensity, timbre matching method shows 20-30% increasing in audio quality compared to previous method.

Reference

[1] H. Mu, W. S. Gan and E. L. Tan, "A psychoacoustic bass enhancement system with improved transient and steady-state performance" , in Proc. IEEE Int. Conf. Acoustics, Speech and Signal Processing (ICASSP), Kyoto, Japan, 2012, page 141 –144.
[2] H. Mu, W. S. Gan, and E. L. Tan, "A timbre matching approach to enhance audio quality of psychoacoustic bass enhancement system," in Proc. IEEE Int. Conf. Acoustics, Speech and Signal Processing (ICASSP), Vancouver, Canada, 2013, pp. 36–40.