Strange aftereffect caused by periodic allocation of a frequency domain variant of velvet noise

Hideki Kawahara
Wakayama University, Wakayama Japan

Kyushu University, Hakata, Japan, 14-15 December, 2019
Take home message

- Exposure to periodically allocated frozen FVN (Frequency domain variant of Velvet Noise) makes environmental sounds sound like processed by flanger, for about a few minutes
- Please help how to study this strange aftereffect
- Phase interpolation between periodically allocated frozen FVN and random FVNs provides a continuum between random and periodic sound (counter part to IRN (Iterated Rippled Noise)?)
- MATLAB code and materials are open-sourced

Conclusion: Help!

GitHub

https://github.com/HidekiKawahara/FVN
Audio Equalization And Reverberation

Vesa Välimäki
Aalto University, Finland

Abstract
This talk will review advances in two audio signal processing topics, equalization and artificial reverberation, which are needed in augmented and virtual reality audio. The graphic equalizer is a standard tool in music and audio production, which allows for the fine adjustment of the gain at several frequency bands. The control of the gains can be manual or automatic, depending on the application. The underlying equalization processing structure is either a parallel or a cascade IIR filter. In the past few years, we have learned, at last, how to accurately design such filters. Example applications for automatic audio equalization will be discussed in this talk. Artificial reverberation has a long history, but new exciting ideas are introduced continuously. Likewise, only a portion of artificial reverberation research has focused on the imitation of concert hall acoustics, the modeling of outdoor acoustic environments has become important for gaming, virtual reality, and simulation of noise propagation. The use of velvet noise, a sparse pseudo-random sequence, will be described for creating computationally efficient reverberation effects.

Speaker’s Biography
Prof. Vesa Välimäki is the Vice Dean for research at the Aalto University School of Electrical Engineering, Espoo, Finland. He is a Full Professor of audio signal processing at Aalto University. He earned the Master of Science in Technology and the Doctor of Science in Technology degrees, both in electrical engineering, from the Helsinki University of Technology, Espoo, Finland, in 1992 and 1995, respectively. In 1996, he was a Postdoctoral Research Fellow at the University of Westminster, London, UK. In 2008-2009, he was a Visiting Scholar at the Center for Computer Research in Music and Acoustics (CCRMA), Stanford University, Stanford, CA, USA. He is a Fellow of the AES (Audio Engineering Society), a Fellow of the IEEE, and a Life Member of the Acoustical Society of Finland. He is a Senior Area Editor of the IEEE/ACM Transactions on Audio, Speech, and Language Processing. In 2016, he was the Guest Editor of the special issue of Applied Sciences on audio signal processing. He was the Chairman of the International Conference on Digital Audio Effects, DAFX-08, in 2008, and was the Chairman of the Sound and Music Computing Conference, SMC-17, in 2017.
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Velvet noise

Sparsely allocated +1 or -1 pulses using randomized pulse location and randomized polarity provide smoother impression than white Gaussian noise, when the pulse density exceeds 3000 pulses per second

Velvet Noise itself is strange

**Frequency domain velvet noise**

- phase manipulation function

**Periodic allocation of FVNs**

- continuum from random to periodic
- strange aftereffect by exposure to frozen FVNs

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**Gaussian white noise**

**velvet noise**

**smooth**

- Periodic allocation of FVNs
  - continuum from random to periodic
  - strange aftereffect by exposure to frozen FVNs

**rough**

**How I failed to …**

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**Grade:**

- Broadband noise:
  - Velvet noise
  - -RASI noise

**Average impulse density [1/s]**

- 300
- 600
- 900
- 1200
- 1500
- 1800
- 2100
- 2400
- 2700
- 3000
- 3300
- 3600
- 3900
- 4200
- 4500
- 4800
- 5100
- 5400
- 5700
- 6000
- 6300
- 6600
- 6900
- 7200
- 7500
- 7800
- 8100
- 8400
- 8700
- 9000
- 9300
- 9600
- 9900
- 10200
- 10500
- 10800
- 11100
- 11400
- 11700
- 12000
- 12300
- 12600
- 12900
- 13200
- 13500
- 13800
- 14100
- 14400
- 14700
- 15000
- 15300
- 15600
- 15900
- 16200
- 16500
- 16800
- 17100
- 17400
- 17700
- 18000
- 18300
- 18600
- 18900
- 19200

**Smooth**

- 2

**Slightly smooth**

- 1

**Equal**

- 0

**Slightly rough**

- -1

**Rough**

- -2

**Very rough**

- -3
What is velvet noise?


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Gaussian white noise

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**Smooth**

- Grade:
  - Smooth
  - Slightly smooth
  - Equal
  - Slightly rough
  - Rough
  - Very rough

**Rough**

- Broadband noise:
  - Velvet noise
  - RASI noise

- Average impulse density [1/s]
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FVN: Frequency domain variant of Velvet Noise

Allocating a very smooth phase manipulation function on the frequency axis based on a rule similar to FVN provides a frequency domain representation of FVN, a TSP (Time Stretched Pulse)

Inverse Fourier transform of the frequency domain representation of FVN yields a unit FVN which sounds like a noise burst
FVN: Frequency domain velvet noise

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Localization in the time domain

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**Conventional windowing functions are harmful for phase analysis**

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**Safe windowing function for phase analysis**

\[
w(t; f_c, c_{mag}) = \exp(2j\pi f_c t) \sum_{k=0}^{5} a_k \cos \left( \frac{2\pi k t}{5c_{mag}f_c} \right)
\]

\[
\{a_k\}_{k=0}^{5} = \{0.2624710164, 0.4265335164, 0.2250165621, 0.0726831633, 0.0125124215, 0.0007833203\} \tag{2}
\]
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Unit FVN: example

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**Phase**

**Waveform**
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Group delay:
compact representation of an FVN

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Periodic allocation of FVNs

each line represents group delay of an FVN

temporally variable frequency weighted phase mixing

random
temporally variable frequency weighted phase mixing

mixed source

frozen

temporally variable frequency weighted phase mixing

IFFT
temporally variable frequency weighted phase mixing

mixed source

random

frozen frequency (Hz)

random frequency (Hz)
Strange aftereffect by exposure to periodic FVN

Exposure to periodically allocated frozen FVN (Frequency domain variant of Velvet Noise) makes environmental sounds sound like processed by flanger, for about a few minutes.
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**Conclusion: Help!**

400ns

5ms

10ms

1000ns

45s

independent clock for D/ A and A/D

fluctuation of sound propagation time for 50cm
I failed to ...

- test using 2 AFC
  
  - I was obsessed a hypothesis of adaptation to propagation delay on the basilar membrane

- find what types of sounds show salient aftereffect
  
  - Environmental sounds sounded strange but voices and music on podcasts did not sound very strange

- find minimum exposure to induce this strange aftereffect
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Thank you! Q & A, please HELP!
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Time-frequency masking: lossy coding of information

On Time-Frequency Masking in Voiced Speech
Jan Skoglund, Member, IEEE, and W. Bastiaan Kleijn, Fellow, IEEE

Abstract — This paper addresses the issue of masking of noise in voiced speech. First, we examine the audibility of cyclostationary narrow-band noise bursts added to voiced speech generated by synthetic excitation. Varying the temporal location of noise within a pitch cycle corresponds to varying its phase spectrum. Using this fact, we found that a change of phase of the noise in the high frequency region is more perceptible for a low-pitched sound than for a high-pitched sound. We then propose a pitch-dependent temporal weighting function which can be employed in quantization of pitch cycle waveforms. In a second experiment, we found that the audibility of high-frequency noise added to natural speech can be significantly reduced using this weighting function.

Index Terms — Auditory masking, phase spectrum, speech coding, temporal weighting.
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Fig. 5. Composite of cyclostationary noise and impulse train. The phase position of the noise is $\varphi = 3\pi/2$.

Fig. 6. Vowel spectrum used in the experiments. The power density spectrum of the target noise ($f_c = 3200$ Hz and $f_c = 1600$ Hz) is shown at a TMR$_{f_c} = 0$ dB.
Masking inside one pitch period

Fig. 8. Average audibility thresholds and the standard deviations (vertical bars) for different noise burst positions within a pitch cycle, normalized for $\varphi = 0$. Noise center frequency $f_c = 3200$ Hz.
Phase and timbre

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Phase and timbre

400Hz

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The effects of temporal asymmetry on the detection and perception of short chirps

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Abstract

There is an intriguing contrast between the physiological response to short frequency sweeps in the brainstem and the perception produced by these sounds. Dau et al. (2000) demonstrated that optimised chirps with increasing instantaneous frequency (up-chirps), designed to compensate for spatial dispersion along the cochlea, enhance wave V of the auditory brainstem response (ABR), by synchronising excitation of all frequency channels across the basilar membrane. Down-chirps, that is up-chirps reversed in time, increase cochlear phase delays and therefore result in a poor ABR wave V. In this study, a set of psychoacoustical experiments with up-chirps and down-chirps has been performed to investigate how these phase changes affect what we hear. The perceptual contrast is different from what was reported at the brainstem level. It is the down-chirp that sounds more compact, despite the poor synchronisation across channels and phase delays up to 20 ms. The perceived ‘compactness’ of a sound is apparently more determined by the fine structure of excitation within each peripheral channel than by between-channel phase differences. This suggests an additional temporal integration mechanism at a higher stage of auditory processing, which effectively removes phase differences between channels. © 2001 Elsevier Science B.V. All rights reserved.

Key words: Chirp signal; Cochlear phase delay; Temporal integration; Auditory image
Compensation of propagation delay on the basilar membrane does not help!

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Transfer function

- Raw
- 1/3 oct.
- 1/6 oct.

Gain (dB)

Level (rel. MSB)

Level (rel. MSB)

Amplitude

Short impulse response

Smoothed response power

Amplitude transfer function (1/6 oct.)

Frequency (Hz)
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