MARE 502, Advanced Topics in Computer Music

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19 November 2009

Outline of this Lecture

Questions

- What is the difference between unipolar and bipolar signals?

Recapitulation

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- How does ring modulation affect incoming sinusoidal signals?

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- What is the frequency modulation $C : M$ ratio; what is the frequency modulation index?
- History: who discovered frequency modulation?

Phase Vocoder Overview

- Phase vocoder analyses and resynthesises a signal
- Analysed signal can be changed before resynthesis!
- Phase vocoder uses (inverse) Fourier transform (FFT)

[a]Source: William A. Sethares (2007). Rhythm and Transforms. Springer.
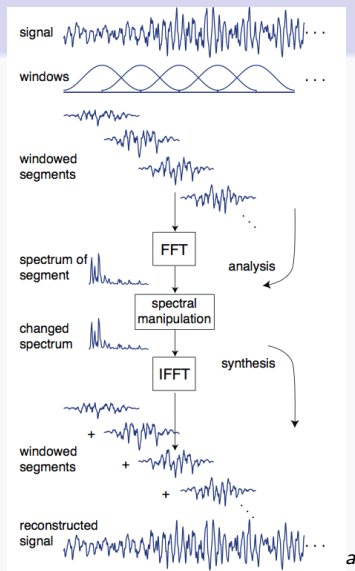
- Read analysis at different speed (and backwards), without changing the pitch and spectrum
- Changing the pitch without changing the speed
- Changing the spectrum
- Combining the techniques above
- . . .

Changing the Analysis II

Changing speed
pvoc.csd, pvoc2.csd

Changing pitch
pvoc3.csd

Changing spectrum (filtering)
pvsanal-filter.csd, pvsanal-bandpass.csd, pvsanal-arp.csd

Other
pvsanal-freeze.csd, pvsanal-blur.csd

Phase Vocoder Analysis

Principle restriction

- Either high temporal resolution
- Or high frequency resolution

Temporal Resolution

- Temporal resolution depends on window size.
- Typical window size: between 512 and 4096 samples (powers of 2 are particular efficient)

Formula

temporal resolution = window size / sampling rate

sampling rate = 44100 Hz
window size = 2048
–> temporal resolution = 46 msec

Note: in transients (e.g. note attacks) signal might change faster – smaller window size might be necessary

Frequency Resolution I

- Each analysis frame consists of set of *bins*: represent energy at different frequency bands
- Bins are distributed *lineary* over spectrum: resolution particularily restricted for lower frequency bands

Formula (reverse of temporal resolution)

frequency resolution of bins = sampling rate / window size

Frequency Resolution II

Example

sampling rate $= 44100$ Hz
window size $= 2048$
$\rightarrow$ frequency resolution $= 21.5$ 43.06 Hz

Note: low note on the piano about 80 Hz: frequency resolution of bins only $1/4$ octave at low end – larger window size would be necessary

- Phase vocoder takes also phase into account: frequency of any bin can deviate up and down
- Only 1 frequency per bin: frequencies in adjacent bins (e.g., different partials) bunch together

Overlapping Windows

- Overlapping windows allow to for both higher temporal and frequency resolution
- But: signal gets "smeared" over time (sounds like some kind of reverb)

Realtime

Obvious restriction: time line of realtime input sound cannot be changed

Resynthesis by Additive Synthesis

- Resynthesis more efficient (e.g., playing only few analysis bins might be sufficient)
- Further sound processing techniques possible, e.g.,
  - Resynthesis can use other function tables besides sine waves
  - Only some subset of the FFT bins is resynthesised
  - with several resyntheses together, one can gradually fade in different parts of the resynthesis, creating various "filtering" effects

Example

pvsanal-pvsadsyn.csd

Compositional Examples

Trevor Wishart (1986) VOX 5 (part of the VOX Cycle). 6:13 min.

Hans Tutschku (1995). *Sieben Stufen*. 13:00 min.
http:
//www.tutschku.com/content/works-siebenstufen.en.php

Further Comments

More advanced phase vocoder software: Audiosculpt (SuperVP) from IRCAM

Linear Predictive Coding (LPC)

Linear predictive coding (LPC) analyses the spectral envelope of a signal. It is particularly useful for signals where the spectrum does indeed change considerably (e.g., speech).

Examples

lpc1.csd, lpc2.csd

Further Analysis-Resynthesis Techniques

Several refined analysis-resynthesis techniques have been developed recently that address harmonic and inharmonic components specifically. Some of these are already supported by Csound

- ATS (Analysis – Transformation – Synthesis) https://ccrma.stanford.edu/~juan/ATS.html, Csound supported (http://www.csounds.com/manual/html/SpectralATS.html)
- Loris http://www.cerlsoundgroup.org/Loris/, Csound supported http://www.csounds.com/manual/html/loris.html
- Spectral Modeling Synthesis (SMS) http://mtg.upf.edu/technologies/sms

Compositional Example

Application of LPC

Paul Lansky (1988). Notjustmoreidlechatter. 7:57 min.
`http://silvertone.princeton.edu/~paul/sounds/`
`notjustmoreidlechatter.mp2`

Summary

- Phase vocoder
- Other analysis-resynthesis techniques

Exercises

- Execute and study the provided examples, in particular the phase vocoder examples
- Play with these examples by changing various parameters in order to understand their effect
- Try out further opcodes/techniques for changing phase vocoder analyses before resynthesis. Overviews of Csound's phase vocoder opcodes is provided at the following URLS
  - http://www.csounds.com/manual/html/SpectralRealTime.html
  - http://www.csounds.com/manual/html/SpectralTop.html