AN AMPLITUDE- AND FREQUENCY-MODULATION VOCODER FOR AUDIO SIGNAL PROCESSING

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Overview

- Motivation
- Fields of application
- Modulation analysis/synthesis
- Modulation processing
- Spectrograms/audio samples
  - Modulation detail modification
  - Music transposition
  - Key mode conversion
- Summary

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Motivation

*From a **perceptual** view, audio signals are composed of low bandwidth and low frequency sub-processes, which **modulate** much higher carrier frequencies.*

- Modulation decomposition?
- Goal: intuitive access to perceptually relevant parameters (pitch, roughness, timbre)
- Ill-defined: Infinite number of possible decompositions
- Border conditions of a suitable decomposition:
  - Carriers as ‚sketch' representation => **signal adaptive**
  - Modification at minimal artifacts => **perceptually meaningful**
  - Fine grain scalability towards ‚*transparency*' => **seamless** transition from **parametric** to **waveform** representation
  - Appropriate synthesis

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Fields of application

- Audio effects (studio, music production)
  - Pitch manipulation
  - Tremolo, Vibrato (slow variable: < 20Hz)
  - Roughness (fast variable: > 20 Hz) [14]-[16]
- Efficient audio coding methods
  - Fine grain scalable audio coding [1]
  - Bandwidth replication [20]
- Semantic audio signal processing
  - Source separation using modulation features (‚common fate')
- Hearing aids [9]
- Research tool
  - Evaluate influence of fine vs. coarse structure in human auditory perception via creation of „audio chimaeras" [11]

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Modulation analysis/synthesis: principle

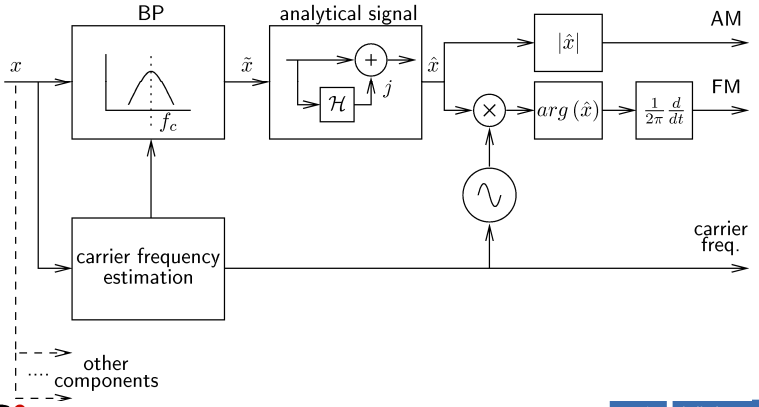
- Time-blockwise decomposition into sets of sub-band coefficients, each comprising
  - Carrier
  - Amplitude modulation (AM)
  - Frequency modulation (FM)
- Sub-bands centered at carriers in local spectral **centers of gravity (COG)**

=> Spectral segmentation task

- **Signal adaptive** alignment of sub-bands
- **Perceptual** criteria (critical bands)
- **Seamless coverage** of spectrum by sum of all sub-bands

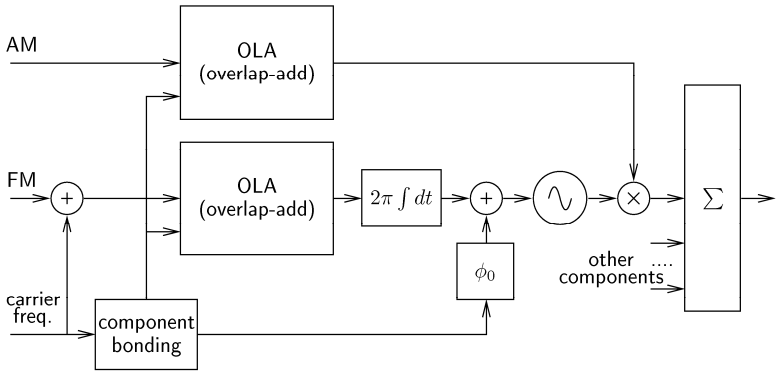
Modulation analysis/synthesis: system (1/2)

- Analysis: analytical sub-band signals
  - AM: absolute value (envelope)
  - FM: instantaneous frequency (IF) from derivative of phase



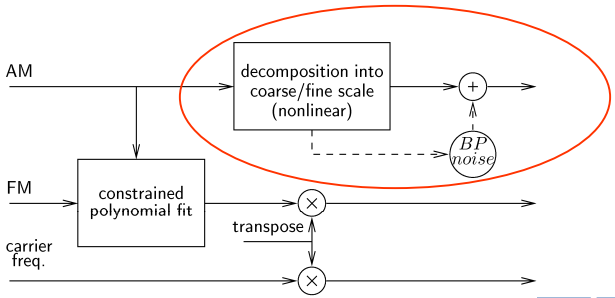
Modulation analysis/synthesis: system (2/2)

- Synthesis
  - Component bonding for carrier phase continuity
  - Overlap-add in modulation component domain

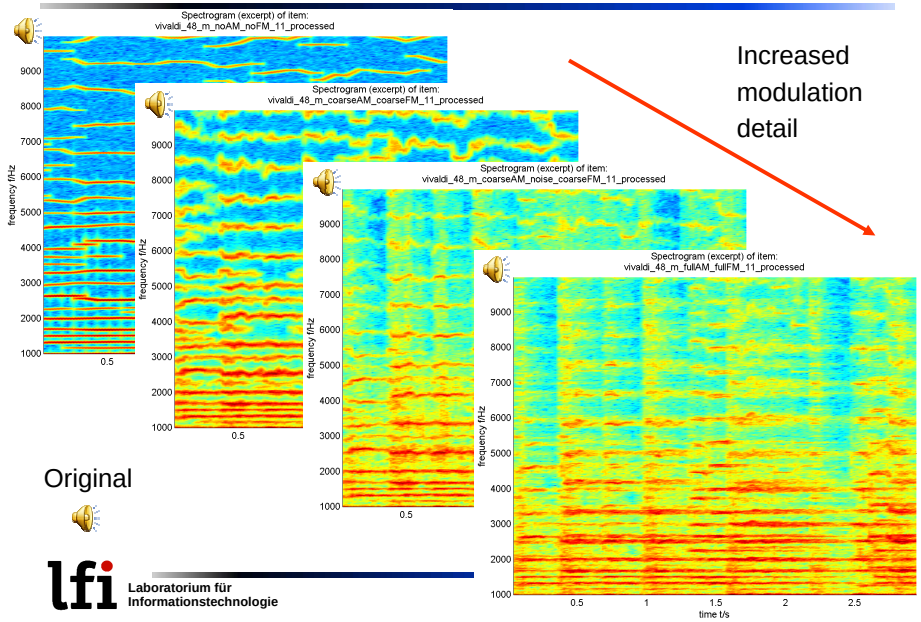


Modulation processing

- Separation of coarse and fine amplitude modulation
  - Coarse AM (=> ADSR envelope parameter "***A**ttack, **D**ecay, **S**ustain, **R**elease*"), "*tremolo*"
  - Fine AM (noise, auditory roughness)
  - Substitution of fine AM with band-limited noise weighted by coarse envelope (generalization of **PNS** [**p**erceptual **n**oise **s**ubstitution])

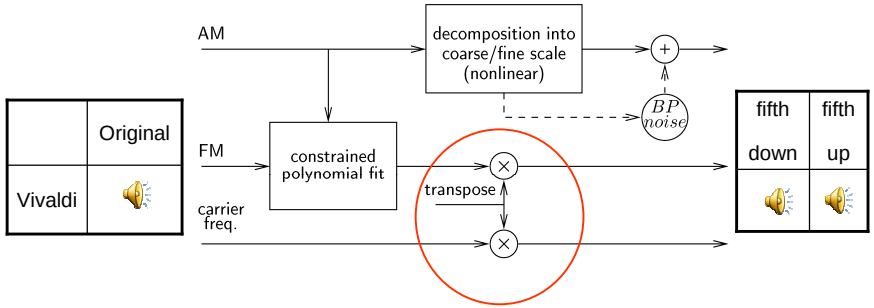


Results: modulation detail modification



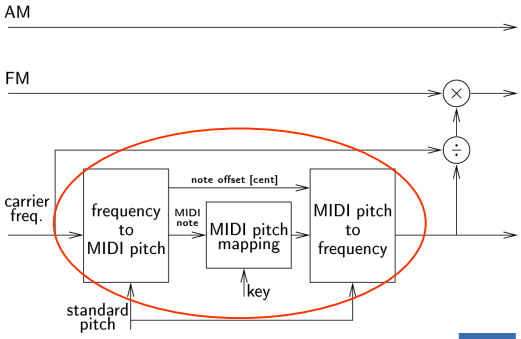
Results: music transposition

- Changed pitch at unchanged playback speed
- Stretch/squeeze of global spectrum
  - Scaling of all carrier frequencies and FM by constant factor
  - Temporal structure of signal is maintained since it is contained in the (unchanged) AM

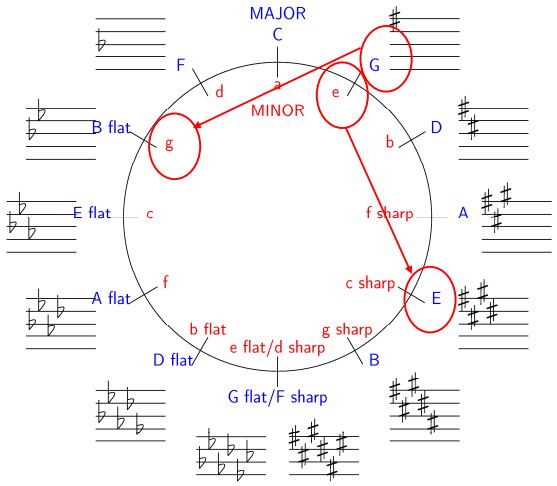


Results: key mode conversion (1/3)

- Key conversion of polyphonic music, e.g. major <-> minor
- Spectral mapping of selected carrier frequencies
  - Mapping of carriers onto MIDI-pitch representation
  - A-priori information: standard pitch and key
  - Shift of selected pitch values according to scale change



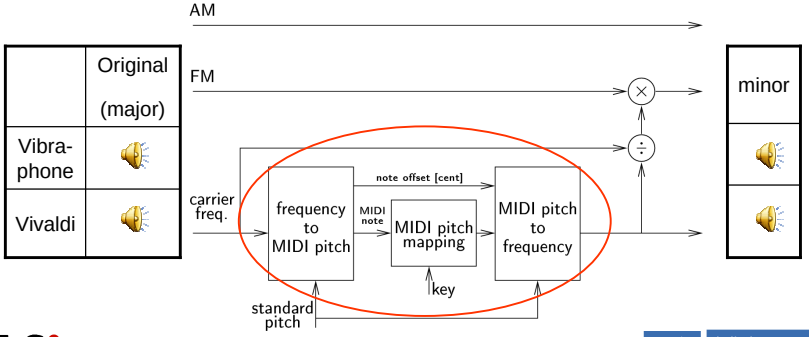
Results: key mode conversion (2/3)



- Mapping of tones according to scale change
- Circle of fifth
- Rules:
  - **Major to minor**: 3 steps counter clockwise
  - **Minor to major**: 3 steps clockwise
- 1 Step == mapping of one tone

Results: key mode conversion (3/3)

- Key conversion of polyphonic music, e.g. major <-> minor
- Spectral mapping of selected carrier frequencies
  - Mapping of carriers onto MIDI-pitch representation
  - A-priori information: standard pitch and key
  - Shift of selected pitch values according to scale change



Summary

- A promising novel method for audio decomposition into sub-band modulation components
- Possible link between waveform and parametric coding
- Spectral decomposition of paramount importance for perceptual quality
- High quality synthesis
- Scalable modulation detail, straightforward handle on pitch
- Applications scenarios
  - Audio codec/bandwidth extension
  - Research tool for auditory perception
  - New exciting audio effects

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End

questions/discussion

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