Spectral Modeling Synthesis: Past and Present
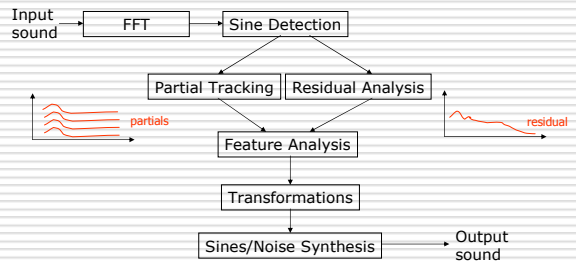
Xavier Serra
MTG-IUA, Universitat Pompeu Fabra
Barcelona, Spain
http://www.iua.upf.es

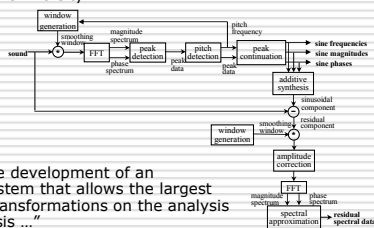
Spectral Analysis/Synthesis

… some history

X. Serra. 1989. *A system for sound analysis / transformation / synthesis based on a deterministic plus stochastic decomposition*. Ph.D. Thesis. Stanford University.

"…The objective is the development of an analysis/synthesis system that allows the largest possible number of transformations on the analysis data before resynthesis …"

Relevant Research Topics (I)

☐ Detection/Estimation of Sinusoids

☐ Partial Tracking

☐ Transient Modeling

☐ Multiresolution

☐ Residual Analysis/Modeling

☐ Feature-based Analysis/Synthesis

☐ Synthesis of Sinusoids/Noise

Relevant Research Topics (II)

- ☐ Morphing
- ☐ Time Scaling
- ☐ Compression/Transmission
- ☐ Source Separation/Transcription
- ☐ Music Content Analysis
- ☐ Instrument/Voice Models
- ☐ Expanded Models
- ☐ Software Environments

Detection/Estimation of Sinusoids (I)

- ☐ George, E. B. (thesis, 1991)
  - ▪ Analysis by synthesis where each sinusoid is subtracted one at a time.

- ☐ Depalle, P.; Hélie, T. (WASPAA, 1997)
  - ▪ parametric modeling of the STFT.

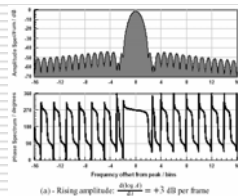- ☐ Goodwin, M. (thesis, 1997)
  - ▪ Matching Pursuit.
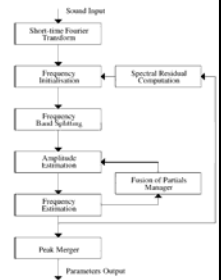
Detection/Estimation of Sinusoids (II)

- ☐ Ding, Y.; Qian, X. (ICMC, 1997)
  - ▪ Global optimization of phase using B-spline quadratic polynomials.

- ☐ Masri, P. (DAFX, 1998)
  - ▪ Measurement of distortion.

- ☐ Marchand, S. (DAFX, 1998)
  - ▪ n signal derivatives.

- ☐ Hainsworth, S.; Macleod, M. (DAFX, 2003)
  - ▪ Frequency reassignment.
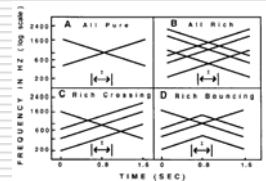

(a) - Rising amplitude: $\frac{d(\log A)}{dt} = +3$ dB per frame

Partial Tracking

- ☐ Depalle, Ph. et alt. (ICMC, 1993)
  - ▪ Hidden Markov Models.

- ☐ Wang, A. (thesis, 1994)
  - ▪ Frequency-Lock Loop.

- ☐ Lagrange, M. et alt. (DAFX, 2003)
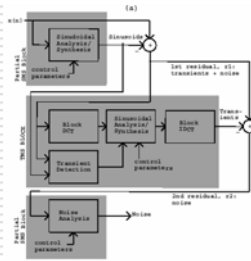 - ▪ Linear prediction of the frequency evolutions.

Transient Modeling

- ☐ Masri, P. (thesis 1996)
  - Analysis of transients to position analysis window.

- ☐ Ali, M. (thesis, 1996)
  - Wavelet Analysis for transients.

- ☐ Verma, T. et alt. (ICMC, 1997)
  - Sinusoids+Transients+ Noise Model.

Residual Analysis/Modeling

- ☐ Hamdy, K. N. et alt. (ICASSP, 1996)
  - Wavelet coding of residual.

- ☐ Goodwin, M. (thesis, 1996)
  - Filter-bank auditory model.

- ☐ Ding Y.; Qian, X. (ICMC, 1997)
  - LPC modeling.

- ☐ Desainte-Catherine, M; Hanna,P. (DAFX, 2000)
  - Parameterization of noise-like sounds.
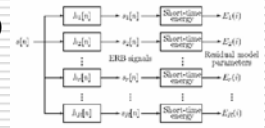
Multiresolution

- ☐ Ellis, D.; Vercoe, B. (ICMC, 1990)
  - constant-Q bandpass filters before sinusoidal modeling.

- ☐ Levine, S. et alt. (WASPAA, 1997)
  - Bounded-Q transform.

- ☐ Polotti P.; Evangelista G. (DAFX, 2001)
  - Harmonic-Band Wavelets.
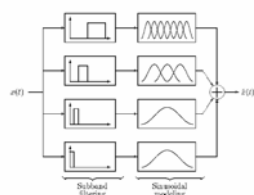
Feature-based Analysis/Synthesis

- ☐ Arcos, J. et alt. (ICMC, 1997)
  - Expression analysis and transformation.

- ☐ Serra, X.; Bonada, J. (DAFX, 1998)
  - High-level features for transformations.

- ☐ Rossignol S. et alt. (DAFX, 1999)
  - Vibrato processing.

- ☐ Gómez, E. et alt. (DAFX, 2003)
  - Melodic transformations.

- ☐ Gouyon, F. et alt. ((DAFX, 2003)
  - Rhythm transformations.
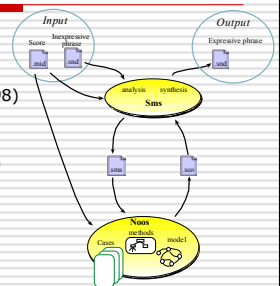
Synthesis of Sinusoids/Noise

- ☐ Rodet, X.; Depalle, Ph. (AES, 1992)
  - IFFT synthesis for sinusoids.

- ☐ Goodwin, M.; Rodet, X.(ICMC, 1994)
  - IFFT synthesis for nonstationary sines.

- ☐ Fitz, K.; Haken, L. (ICMC 1995)
  - Bandwidth Enhanced Sinusoidal Modeling.

- ☐ Goodwin, M. (thesis, 1996)
  - Noise synthesis using Equivalent Rectangular Bands.

sine-wave

FFT with Blackman-Harris 92dB

magnitude spectrum

phase spectrum

Morphing

- ☐ Serra, X. (ICMC, 1994)
  - Featured-based interpolation.

- ☐ Tellman, E. et alt. (ICMC, 1994)
  - Sinusoidal interpolation.
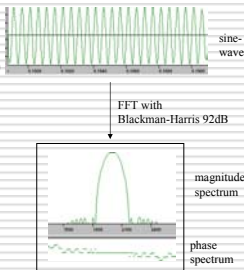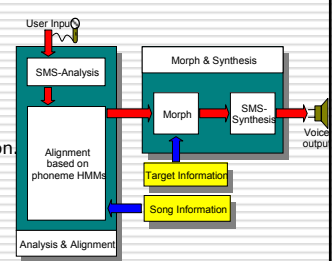
- ☐ Cano, P. et alt. (ICMC, 2000)
  - Voice morphing.

User Input

SMS-Analysis

Morph & Synthesis

Morph

SMS-Synthesis

Voice output

Alignment based on phoneme HMMs

Target Information

Song Information

Analysis & Alignment

Time Scaling

- ☐ Verma, T.; Meng, H. (DAFX, 1998)
  - Using Sines +Transients + Noise Signal Model.

- ☐ Laroche, J.; Dolson, M. (IEEE, 1999)
  - Spectral Peaks.

- ☐ Bonada, J. (ICMC, 2000)
  - Spectral Peak Processing.

Phase

Z^{-1}

Spectrum Phase Generation

Phase

Z^{-1}

Peak Detection

Peak Continuation

Amplitude

Peak Detection

Amplitude
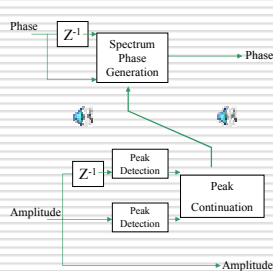
Coding/Transmission

- ☐ Hamdy, K. N. et alt. (ICASSP, 1996)
  - Harmonics plus wavelets.

- ☐ Levine, S. N. (thesis, 1998)
  - Transformations in transform domain.

- ☐ Purnhagen, H.; Meine N. (ISCAS, 2000)
  - MPEG4: Harmonic and Individual Lines plus Noise (HILN).

- ☐ Amatriain, X. et alt. (AES, 2002)
  - Content-based transmission.

Perception Model

selection of relevant components

Parameter Estimation

Parameter Coding

Harmonic Components

Quant

Audio Signal

Model Based Decomposition

Sinusoidal Components

Quant

Mux

Bit Stream

Noise Components

Quant
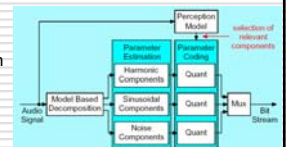
Source Separation / Transcription

- Maher, R. (thesis, 1989)
  - Partial collision and Two Way Mismatch algorithm for F0 detection.

- Virtanen, T. et alt. (ICASSP, 2000)
  - Multipitch analysis and iterative parameter estimation.
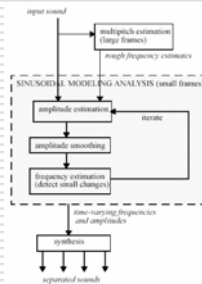
Music Content Analysis

- Herrera, P. et alt. (CBMI, 1989)
  - Descriptors for MPEG-7.

- Heittola, T.; Klapuri, A. (ISMIR, 2002)
  - Identification of drums.

- Gómez, E. et alt. (JNMR, 2003)
  - Melodic description.

- Wang, A. (Shazam, 2003)
  - Audio identification.
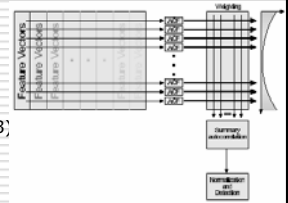
Instrument/Voice Models

- Macon, M. W. et alt. (AES, 1997)
  - Singing voice (Lyricos)

- Haas, J. (MOSART, 2001)
  - Sax synthesizer

- Bonada et. alt. (ICMC, 2001)
  - Singing voice (Vocaloid)

- Laroche, J. (DAFX, 2003)
  - Spectral processing plus TD-PSOLA
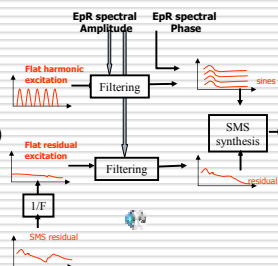
Expanded Models

- Laroche, J. et alt. (ICASSP, 1993)

- Fitz, K. et alt. (ICMC, 1995)

- Ding Y. et alt. (ICMC, 1997)

- Goodwin, M. (thesis, 1997)

- Verma, et alt. (ICMC, 1997)

- Peeters, G. et alt. (ICMC, 1999)
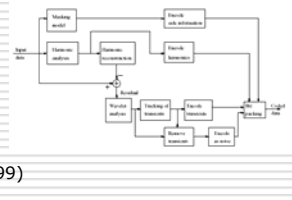
Software Environments

- Serra, X. (LMJ, 1991)
  - SANSY: Lisp environment based on SPIRE

- Fitz, K. et alt. (ICMC, 1995)
  - Lemur

- Loscos, A. et alt.(DAFX, 1998)
  - SMSPerformer

- Amatriain, X. et alt. (ACM, 2002)
  - CLAM
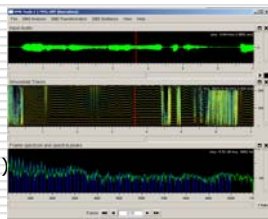
Conclusions

- From speech to audio to music.

- From analysis/synthesis to content processing.

- Beyond signal processing techniques.

- Techniques are ready for many practical applications.

- Need to combine bottom-up with top-down approaches.

Sinusoidal plus Residual Modeling of Musical Sounds: Relevant References
compiled by Xavier Serra, September 2003

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