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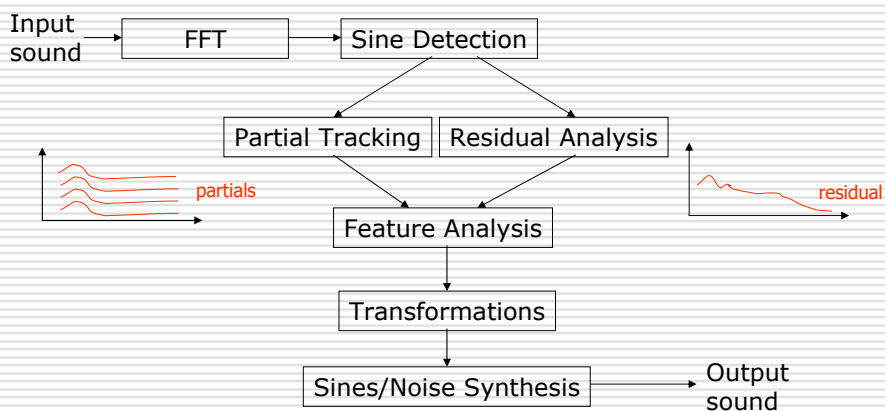
Xavier Serra
MTG-IUA, Universitat Pompeu Fabra
Barcelona, Spain
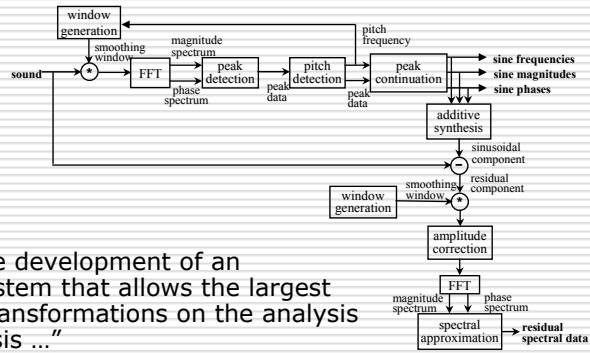http://www.iua.upf.es

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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.
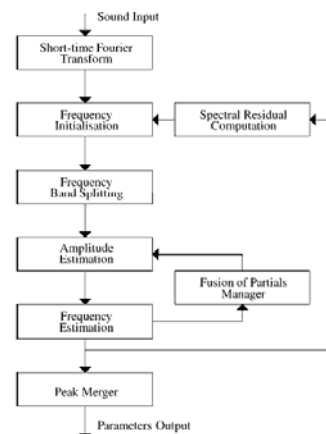
Detection/Estimation of Sinusoids (II)

- ☐ 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

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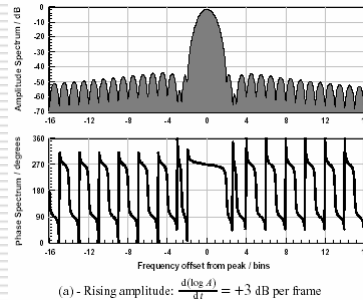
Partial Tracking

- ☐ 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.
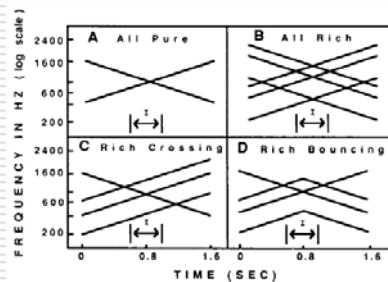
Transient Modeling

- 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.
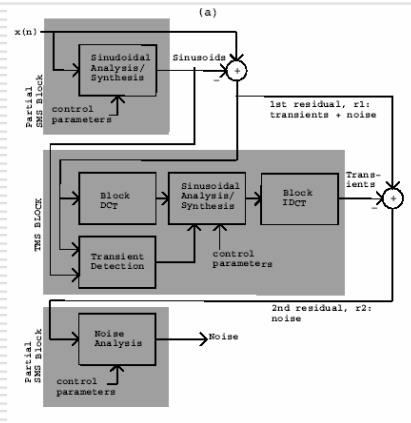
Residual Analysis/Modeling

- 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.
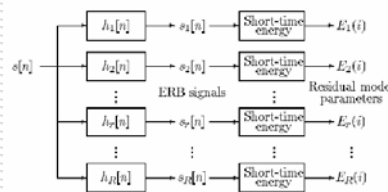
Multiresolution

- [ ] 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.
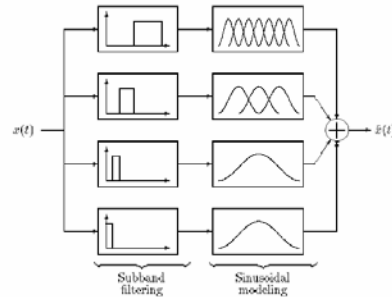
Feature-based Analysis/Synthesis

- [ ] 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.
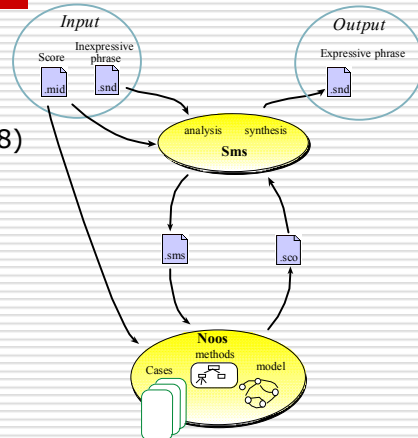
Synthesis of Sinusoids/Noise

- 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
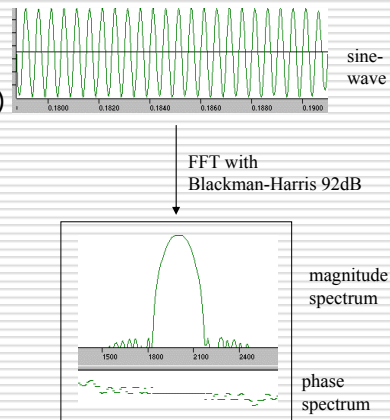
Morphing

- 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
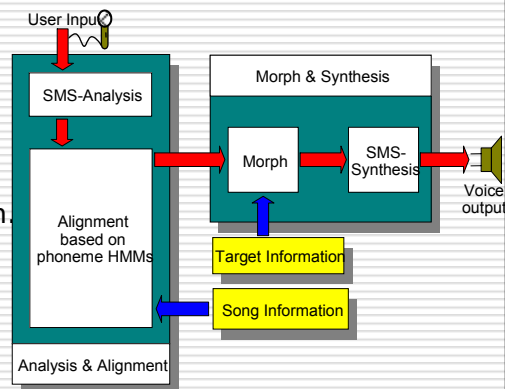
Time Scaling

□ 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

Amplitude — Peak Detection

Peak Continuation

Amplitude
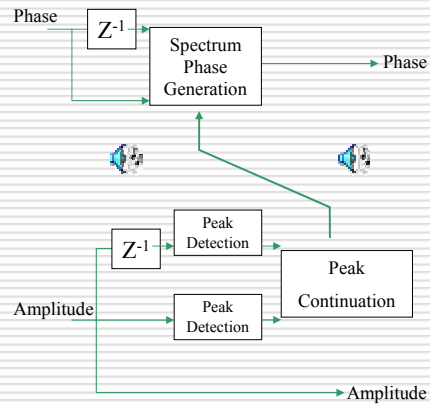
Coding/Transmission

□ 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.
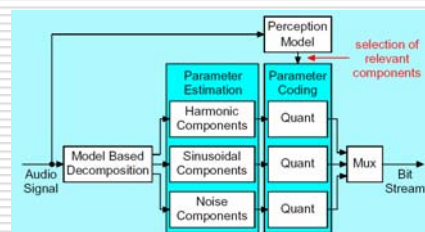
Source Separation / Transcription

- ☐ 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.
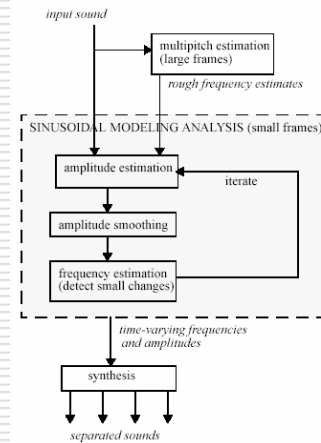
Music Content Analysis

- ☐ 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)
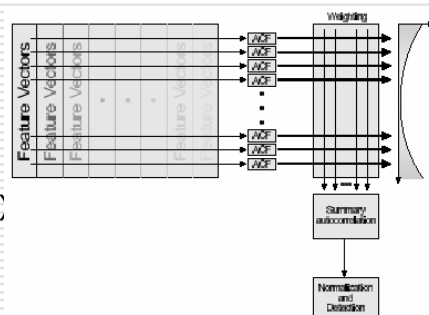
Software Environments

□ 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
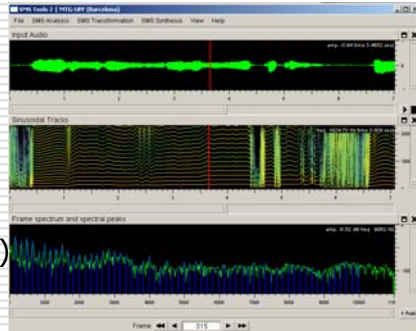
Conclusions

□ 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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