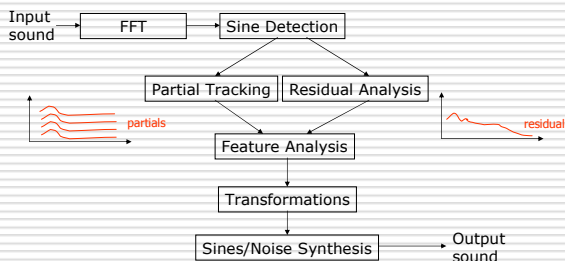


# Spectral Modeling Synthesis: Past and Present

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## Spectral Analysis/Synthesis

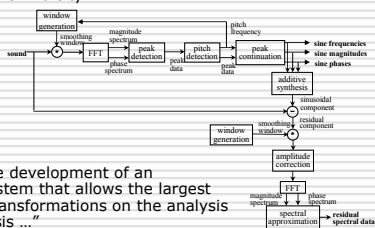


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## ... some history

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 ..."

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## Relevant Research Topics (I)

- Detection/Estimation of Sinusoids
- Partial Tracking
- Transient Modeling
- Multiresolution
- Residual Analysis/Modeling
- Feature-based Analysis/Synthesis
- Synthesis of Sinusoids/Noise

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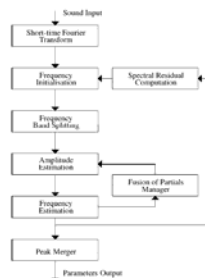
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## Relevant Research Topics (II)

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

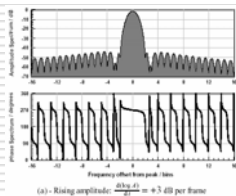
## Detection/Estimation of Sinusoids (I)

- 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.



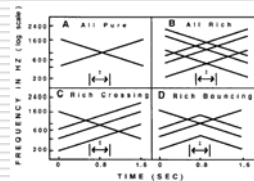
## Detection/Estimation of Sinusoids (II)

- 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.



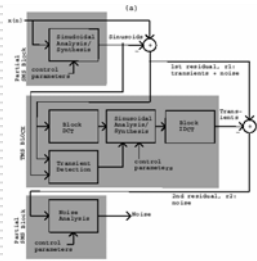
## Partial Tracking

- Depalle, Ph. et al. (ICMC, 1993)
  - Hidden Markov Models.
- Wang, A. (thesis, 1994)
  - Frequency-Lock Loop.
- Lagrange, M. et al. (DAFX, 2003)
  - Linear prediction of the frequency evolutions.



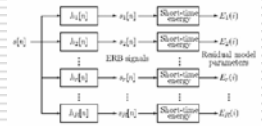
## Transient Modeling

- 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.



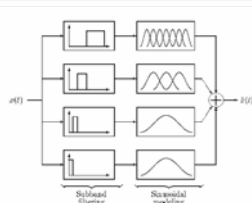
## Residual Analysis/Modeling

- 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.



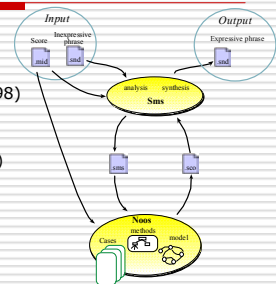
## Multiresolution

- 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.



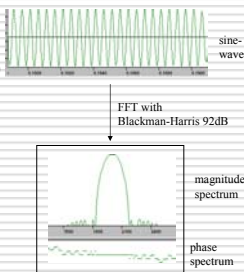
## Feature-based Analysis/Synthesis

- 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.



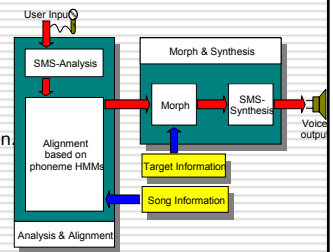
## Synthesis of Sinusoids/Noise

- 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.



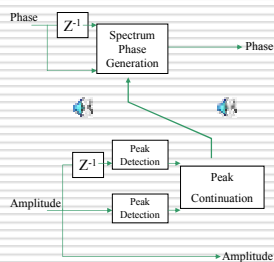
## Morphing

- Serra, X. (ICMC, 1994)
  - Featured-based interpolation.
- Tellman, E. et al. (ICMC, 1994)
  - Sinusoidal interpolation.
- Cano, P. et al. (ICMC, 2000)
  - Voice morphing.



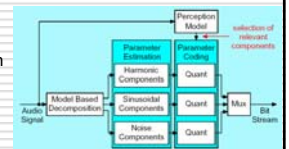
## Time Scaling

- 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.



## Coding/Transmission

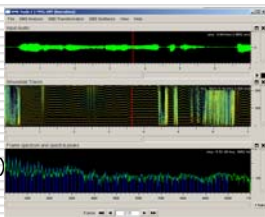
- Hamdy, K. N. et al. (ICASSP, 1996)
  - Harmonics plus wavelets.
- Levine, S. N. (thesis, 1998)
  - Transformations in transform domain.
- Purnhagen, H.; Meine N. (ISCAS, 2000)
  - MPEG4: Harmonic and Individual Lines plus Noise (HILN).
- Amatriain, X. et al. (AES, 2002)
  - Content-based transmission.





## Software Environments

- Serra, X. (LMJ, 1991)
  - SANSY: Lisp environment based on SPIRE
- Fitz, K. et al. (ICMC, 1995)
  - Lemur
- Loscos, A. et al. (DAFX, 1998)
  - SMSPerformer
- Amatriain, X. et al. (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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