Two-Step Modal Identification for Increased Resolution Analysis of Percussive Sounds
(p.117)

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Outline

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What for ?

Tool for the **modal analysis** of **percussive sounds** for:

What for ?

Tool for the **modal analysis** of **percussive sounds** for:

- musical instrument modeling
- synthesize impact sounds between objects for virtual environments
- ...

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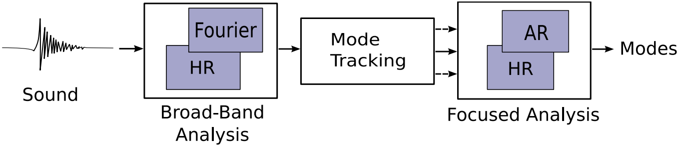
2 steps ?



Two-step modal parameters estimation:

1. **Broad-band analysis** ⇒ global spectro-temporal structure of the sound (with limited frequency resolution)

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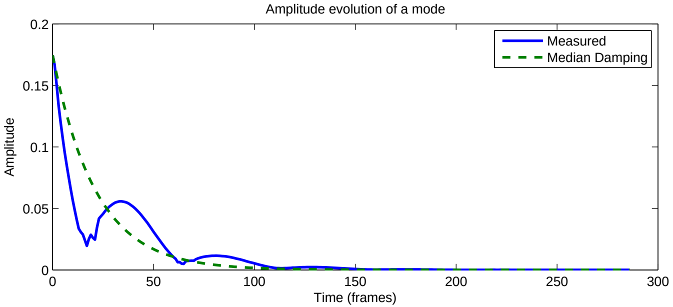
2 steps ?



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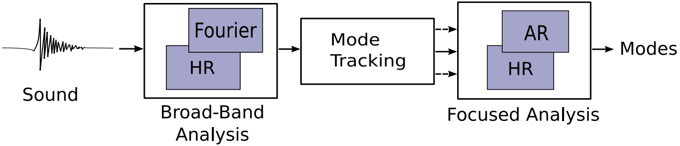
2 steps ?



Two-step modal parameters estimation:

1. **Broad-band analysis** ⇒ global spectro-temporal structure of the sound (with limited frequency resolution)
2. **Focused analysis** ⇒ better modeling of each component identified during the first "pass"

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Interest

- **Flexible method**:

Interest

- **Flexible method**:
  - **a lot of** *a priori* knowledge

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- **Flexible method**:
  - **a lot of** *a priori* knowledge ⇒ physical model parameter estimation

Interest

- **Flexible method**:
  - **a lot of** *a priori* knowledge ⇒ physical model parameter estimation
  - **not much** *a priori* knowledge

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Interest

- **Flexible method**:
  - **a lot of** *a priori* knowledge ⇒ physical model parameter estimation
  - **not much** *a priori* knowledge ⇒ “realistic enough” sound synthesis

Sound Model

We assume that:

- the signal is made of a **sum of exponentially decaying cisoids**

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- the signal is made of a **sum of exponentially decaying cisoids**
- the physical properties of the impacted object remain constant $\Rightarrow$ **mode frequencies and damping factors are constant**

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Sound Model

We assume that:

- the signal is made of a **sum of exponentially decaying cisoids**
- the physical properties of the impacted object remain constant $\Rightarrow$ **mode frequencies and damping factors are constant**

$$\hat{x}(t) = \sum_{k=1}^{K} A_k e^{\delta_k t} e^{j(2\pi f_k t + \phi_k)}$$

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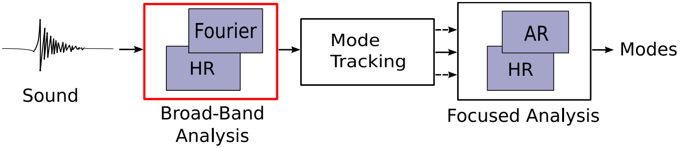
Broad-Band Analysis



Fourier-Based Analysis:

- STFT $\Rightarrow$ one spectrum per frame
- Peaks picking using improved amplitude, frequency and phase estimation techniques [Lagrange *et al.* JAES'07]
- δ_k estimated by fitting an exponential on the amplitude profile, or Energy Decay Relief [Jot ICASSP'92] of one mode

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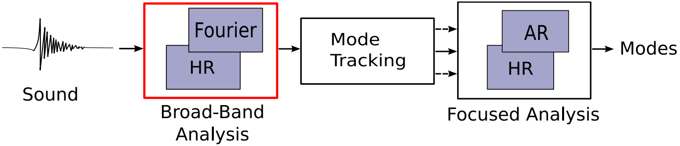
Broad-Band Analysis



High Resolution Analysis:

- Using the adaptive implementation of the ESPRIT algorithm [Badeau *et al.* WASSPA'05]
- Frame-based analysis:
  - pre-processing
  - f_k and δ_k estimation
  - A_k and ϕ_k estimation

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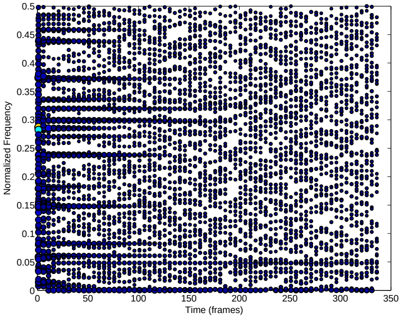
Broad-Band Analysis



Corresponding **sound**

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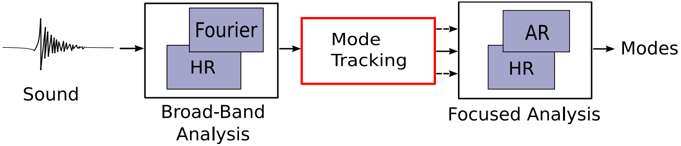
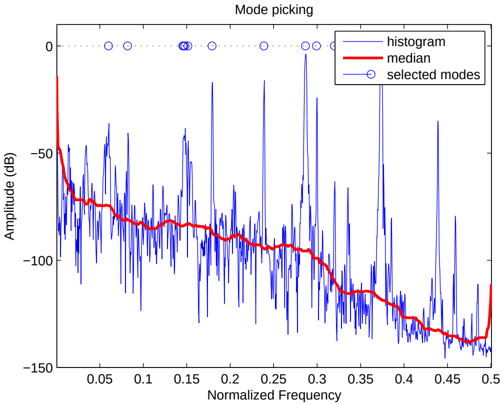
Mode identification and Tracking



1. Frequency marginal to identify main modes

Mode identification and Tracking



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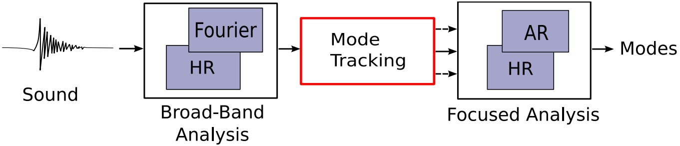
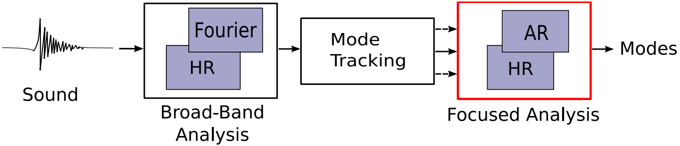
Mode identification and Tracking



1. Frequency marginal to identify main modes
2. Detected modes tracked over time using standard frequency proximity criterion

Focused Analysis



1. **Selection** of the partial track to process
   - amplitude high enough, lasts long enough
   - error between measured and estimated amplitude profiles high enough:

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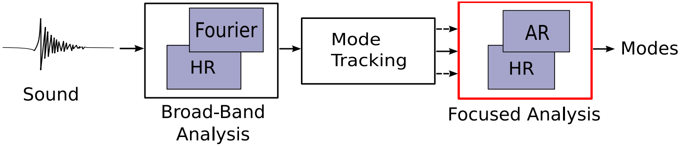
Focused Analysis



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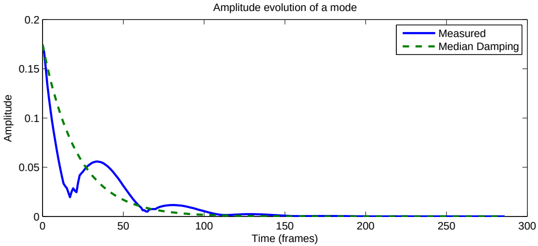

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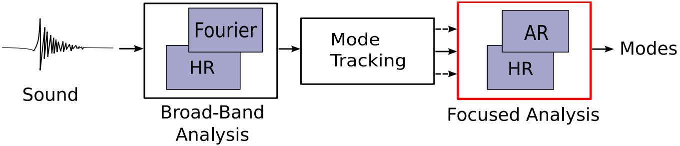
Focused Analysis



1. **Selection** of the partial track to process
2. **Pre-processing** [Laroche, JASA'93]
   - complex FIR filter around f_k
   - modulation + downsampling

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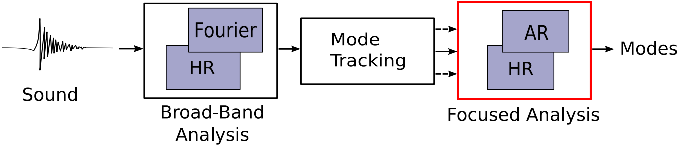
Focused Analysis



1. **Selection** of the partial track to process
2. **Pre-processing** [Laroche, JASA'93]
3. Estimation of **frequencies and damping**
   - AR analysis as done in [Karjalainen *et al.*, EUSIPCO'05]
   - HR analysis using a non adaptive ESPRIT (not frame-based)

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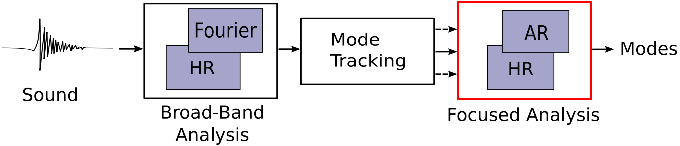
Focused Analysis



1. **Selection** of the partial track to process
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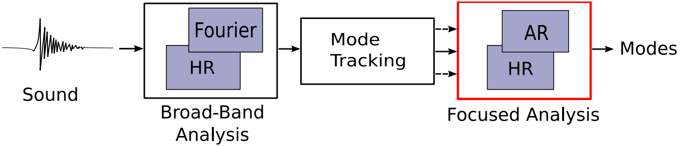
Focused Analysis



1. **Selection** of the partial track to process
2. **Pre-processing** [Laroche, JASA'93]
3. Estimation of **frequencies and damping**
4. Leat Squares **amplitude and phase** estimation
5. **Sorting** components
   - discarding: $\delta_k > 0$ and $|f_{mode} - f_k| > \Delta f_{max}$
   - $\frac{A_k}{max(A_k)} >$ threshold

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Synthetic Signals

- A_k: uniform pdf in [0.9, 1]
- δ_k: uniform pdf in [0.0001, 0.001]
- f_k
  - 2 freqs $\in$ [0.2499, 0.2501]
  - 20 freqs $\in$ [0.2, 0.3]

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$\Rightarrow$ 1000 sounds

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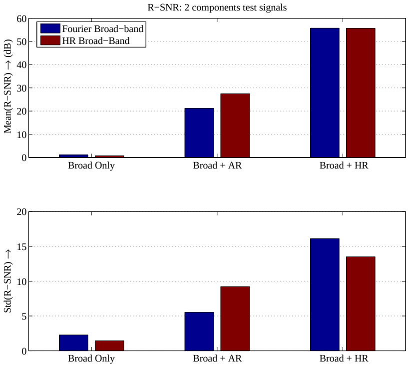
Results: 2 components:



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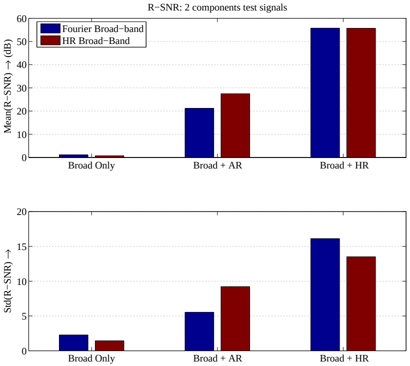

- AR $<$ HR: over-estimation of the number of components using our empirical metric

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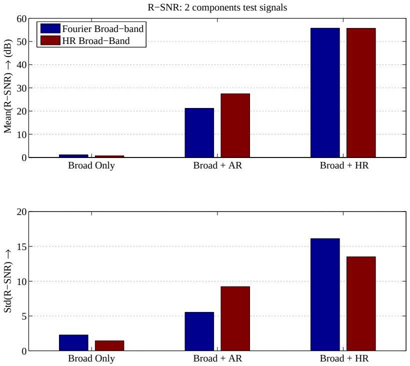

- AR $<$ HR: over-estimation of the number of components using our empirical metric
- HR broad + HR $\approx$ Fourier broad + HR

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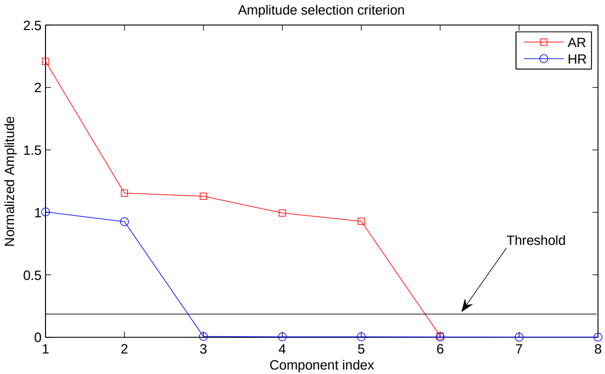

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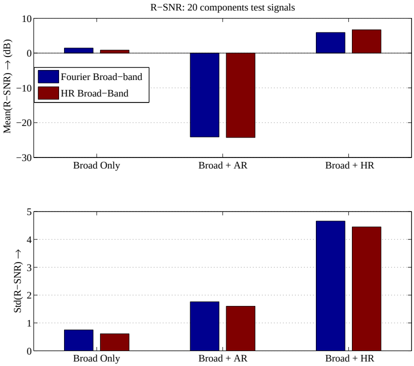
Results: 20 components:



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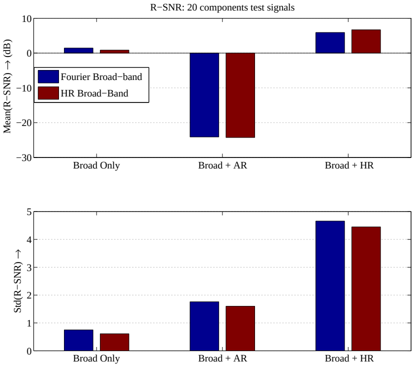
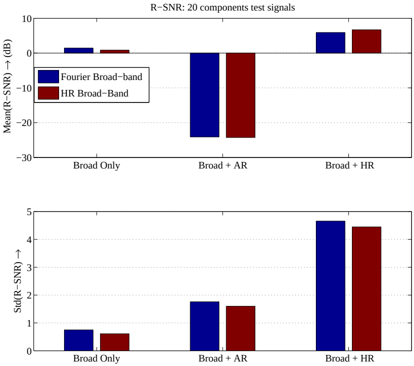
Results: 20 components:



- HR focused analysis improves results for both broad-band analyses

Results: 20 components:



- HR focused analysis improves results for both broad-band analyses
- **Fourier Broadband + HR focused analysis** = good compromise: computation load / good results

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“Real world” cases

Type of sound:

- Metallic plate struck by ceramic hammer

Performance Assessment

- **Context:** Excitation estimation using standard deconvolution method [Laroche *et al.* TSAP'94]

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- We compare HR broadband (state of the art in terms of resolution) and Fourier broadband + AR focused analysis

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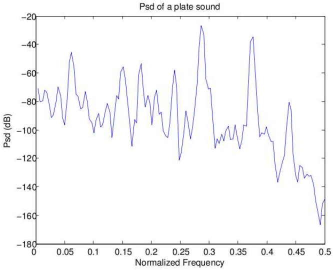
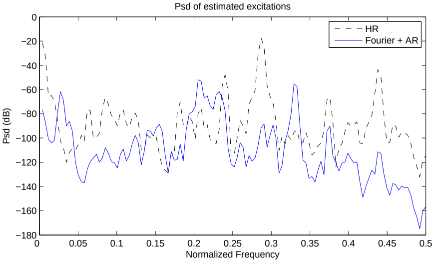
- We compare HR broadband (state of the art in terms of resolution) and Fourier broadband + AR focused analysis
- We compare HR broadband and Fourier broadband + HR focused analysis

HR vs. Fourier-AR:





Original

HR excitation
Fourier + AR excitation

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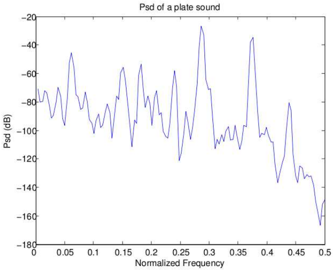
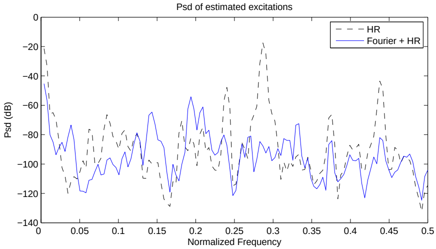
HR vs. Fourier-HR:





HR excitation
Fourier + HR excitation

Original

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Results

- Main modes of the sounds are generally absent from excitation signals
- Presence of strong modes in excitation $=$ artifact of deconvolution method

Conclusion

A two-step analysis scheme for the estimation of modal parameters from recorded sounds.

- alleviating parametrization and manual post-processing
- interest demonstrated in the case of synthetic signals
- interest demonstrated in the context of excitation estimation for source filter modeling

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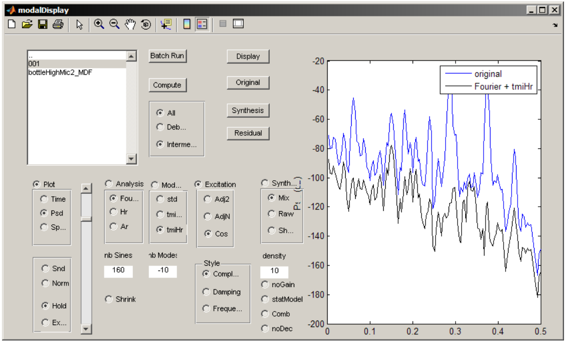

Toolbox available upon request: mathieu.lagrange@mcgill.ca

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Thank you for your attention.

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Questions, comments ?

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