Morphing Instrument Body Models

Henri Penttinen, Matti Karjalainen
& Aki Härmä

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Laboratory of Acoustics and
Audio Signal Processing,
Helsinki University of Technology,
Finland

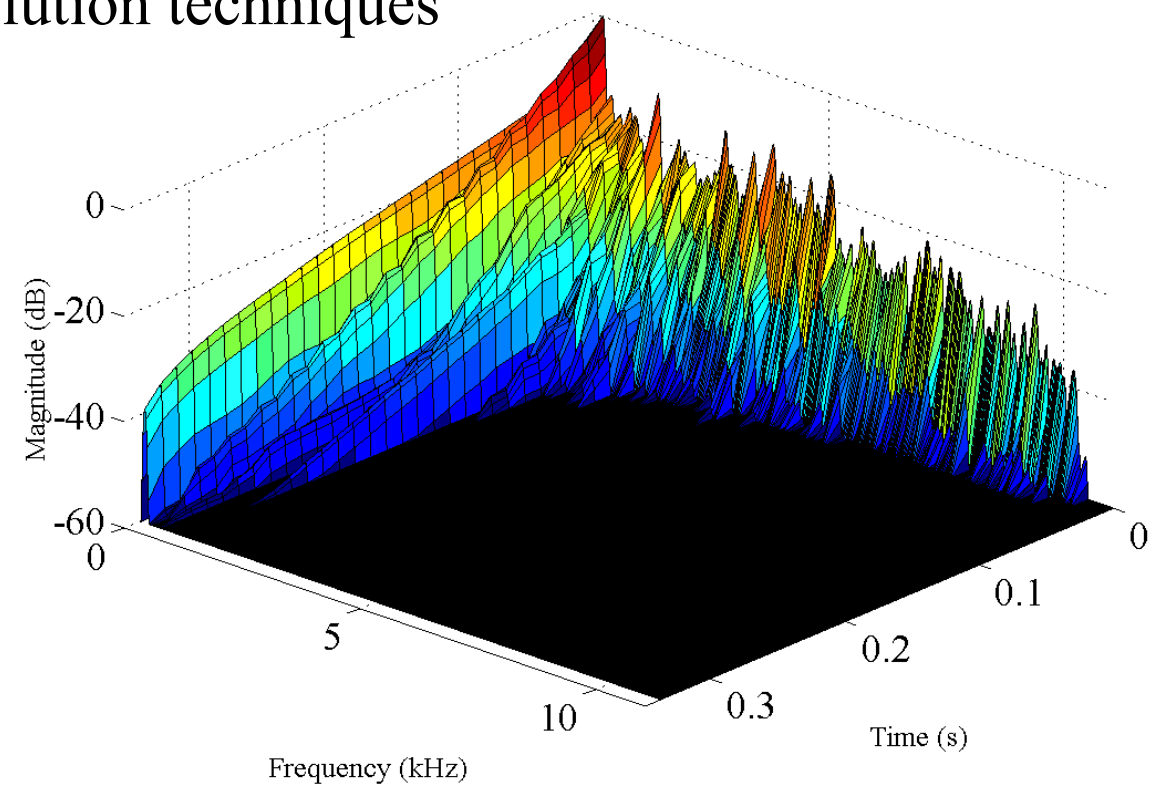
INTRODUCTION

- What is morphing ?
  - Smooth transform from object to another
- What's the beef ?
  - Enlarging audio effect arsenal
  - Beyond morphing ⇒ extrapolation
- Real-time morphing?
  - Why not, if efficient digital filters (order ~ 100) can do it

BODY MODELS

- Purpose of a body: amplify & color instrument sound
- Implementation: bridge to sound radiation modeling with digital filters
- Target response obtained by impact hammer or *f*-deconvolution techniques

Acoustic guitar body response: time-frequency plot



MORPHING PRINCIPLES

- Morphing by varying filter coefficients
- Digital filter principles
  - FIR, IIR(Direct form, lattice), WFIR, ***WIIR(!)***
- Methodological possibilities:
  - Single filter structures
    - Morphing from one complete model to another
  - Multi-part filter
    - E.g., high & low-frequencies separately
  - Discrete resonances
    - Lowest body modes modeled separately

REALIZATION REQUIREMENETS

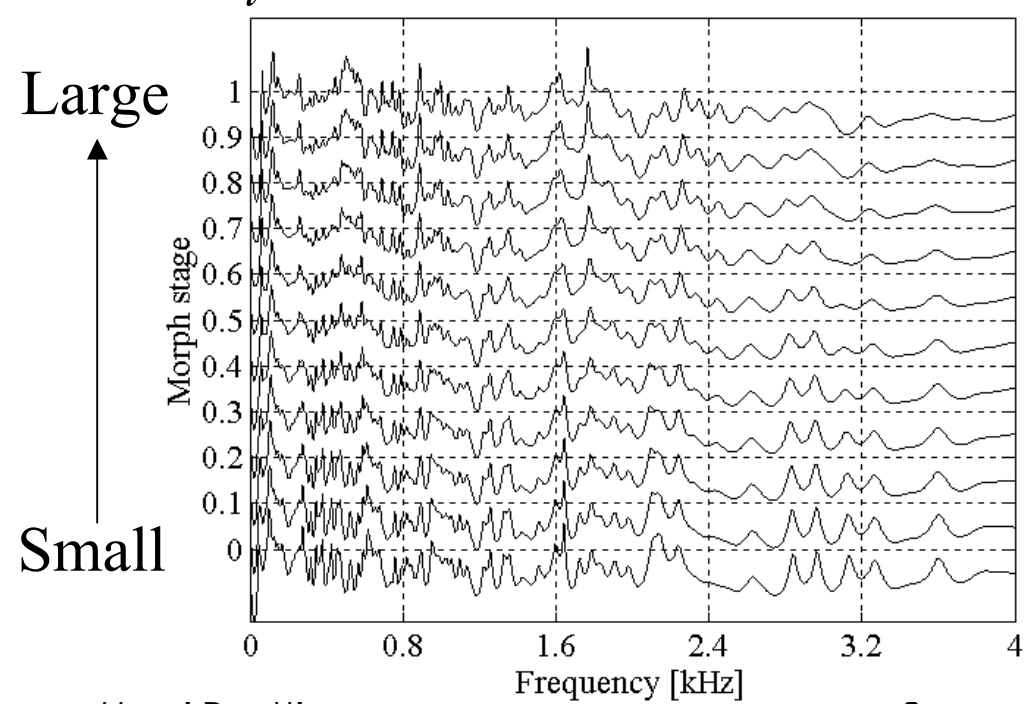
- **Stability** at each morphing stage
  - Not ensured for pole-zero filters represented with polynomial coefficients
  - Ensured for
    - Reflection Coefficients (**RC**)
    - Log Area Ratio (**LAR**) coefficients
- Smooth interpolation
- Numeric precision

INTERPOLATING REFLECTION COEFFICIENTS

- RCs, k_i, recursively from direct form coefficients
- Stable when $-1 \leq k_i \leq 1$

Acoustic guitar:
In steps from
small to large

Body model filters:
WIIR order 100

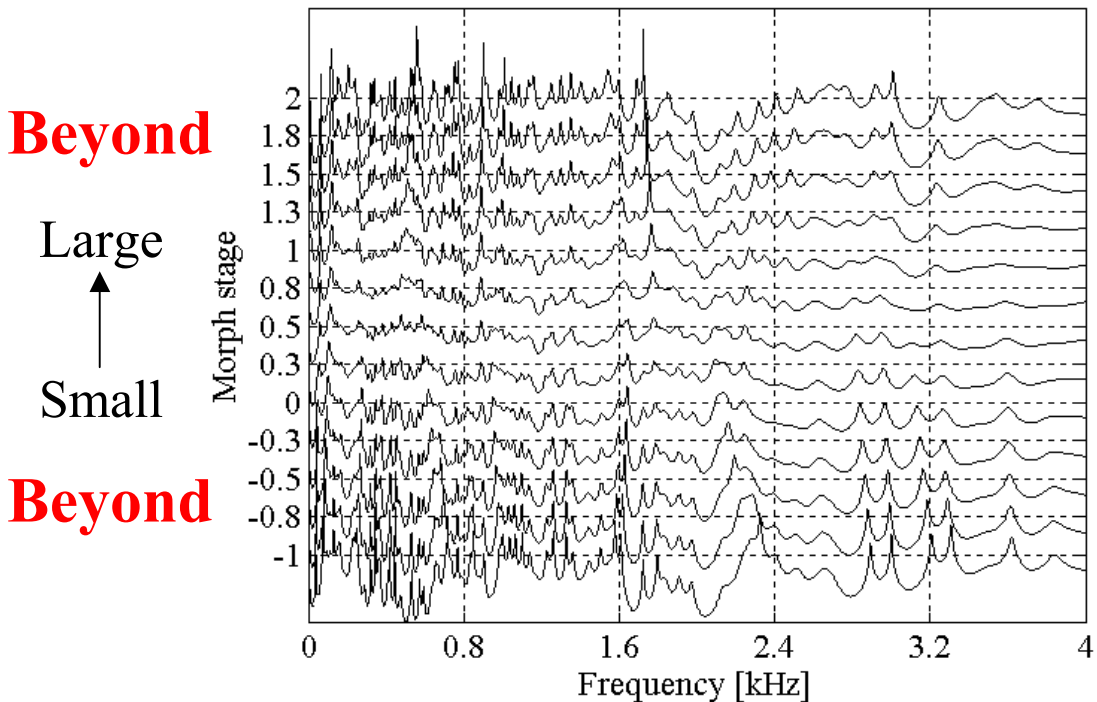


EXTRAPOLATING LOG AREA RATIOS

$$g_i = \log \frac{1+k_i}{1-k_i}$$

- Stable when $-\infty \leq g_i \leq +\infty$

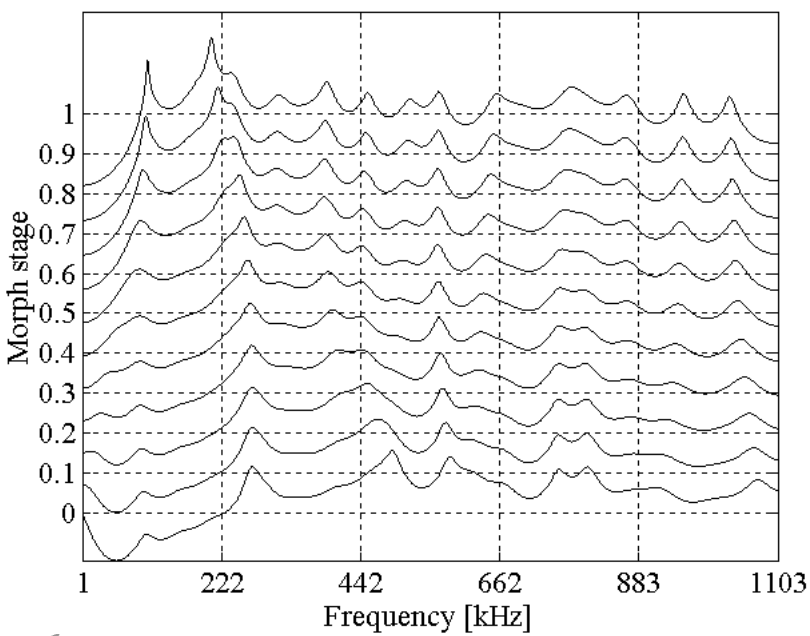
Beyond small and large acoustic guitar:



GUITAR TO VIOLIN MORPHING

- Two lowest body modes:
  - Guitar: 104 & 205 Hz Violin: 270 & 490 Hz

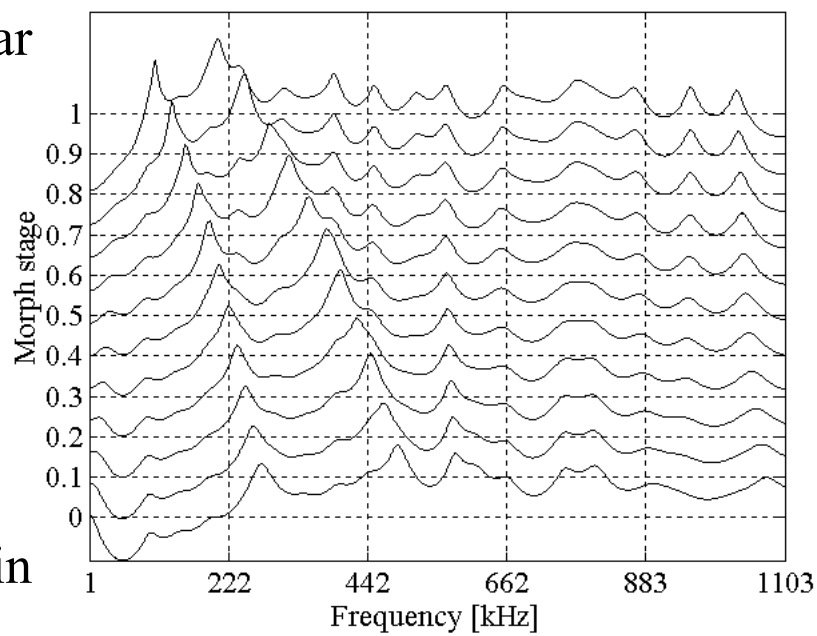
Single structure lattice filter (RC)



Guitar

Violin

Resos. separately & single structure (RC)



CONCLUSIONS

- Morphing by variable body model filters possible
- Stability assured with RC and LAR parameters
- LARs provide extrapolation and hence, out-of-this world instrument bodies
- Stereo effects also possible