Rhythmic Demodulation for Zero-Resource Speech Recognition

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also with

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Motivating Question

What is the data rate of speech?

- Phonetic?
- Syllabic?
- Word?

The syllable in speech recognition:

- Phonological stability → "minimal recognition unit" (Fujimura, 1975)
- Demonstrated importance in human perception (Greenberg, 1997)
- Possible timing cues for theta waves in the brain (Ghitza and Greenberg, 2009)

Main Idea

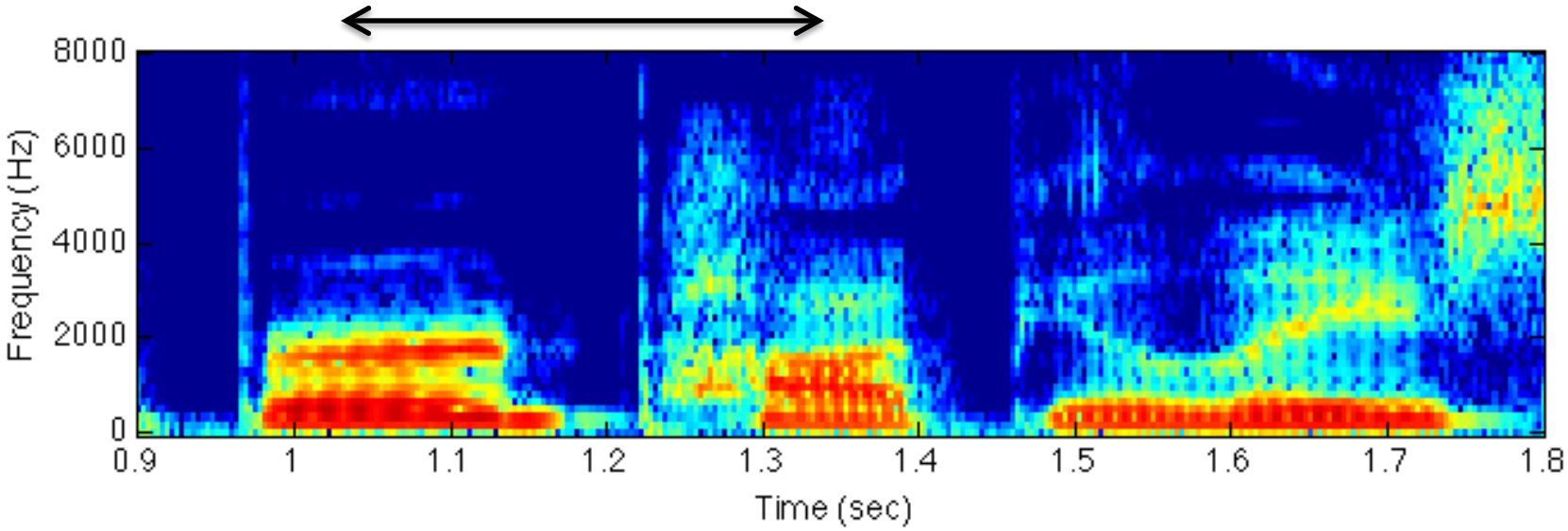
Sources of speaker-dependent temporal variations include:

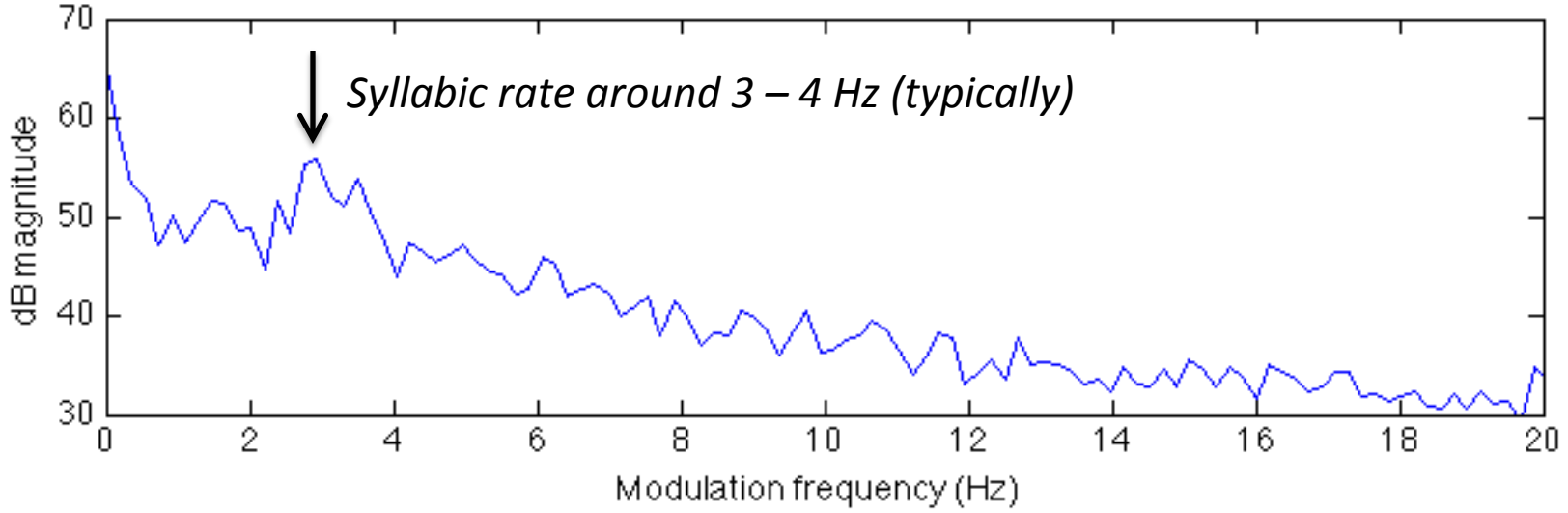
- Speaking rate mismatch
- Prosody, stress, pronunciation

Goal: An acoustic signal model for detecting and normalizing rhythmic variations between spoken terms.

Results: Two feature vector streams for Aren's Same/Different keyword detection evaluation.

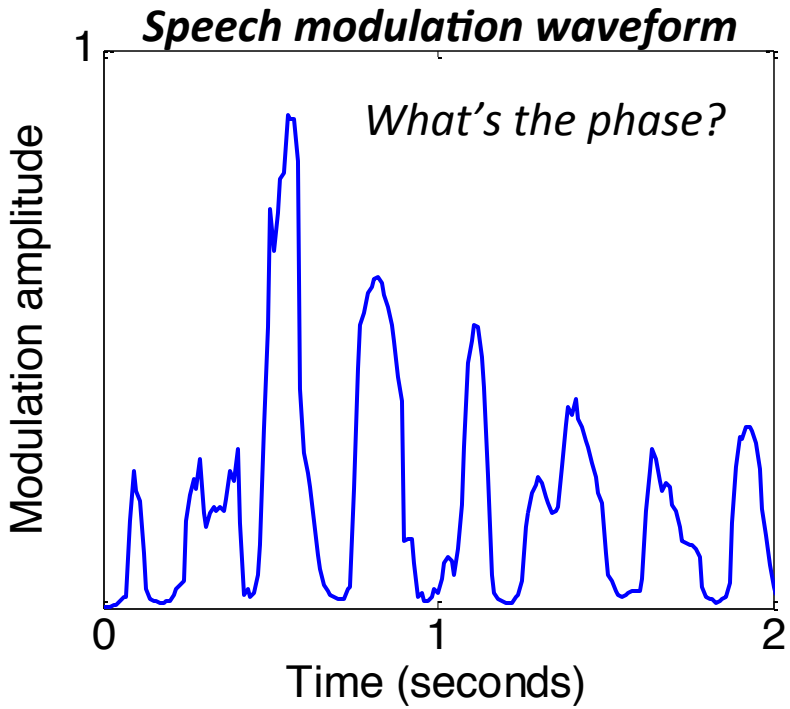
A Physical Descriptor of Speech Rhythm

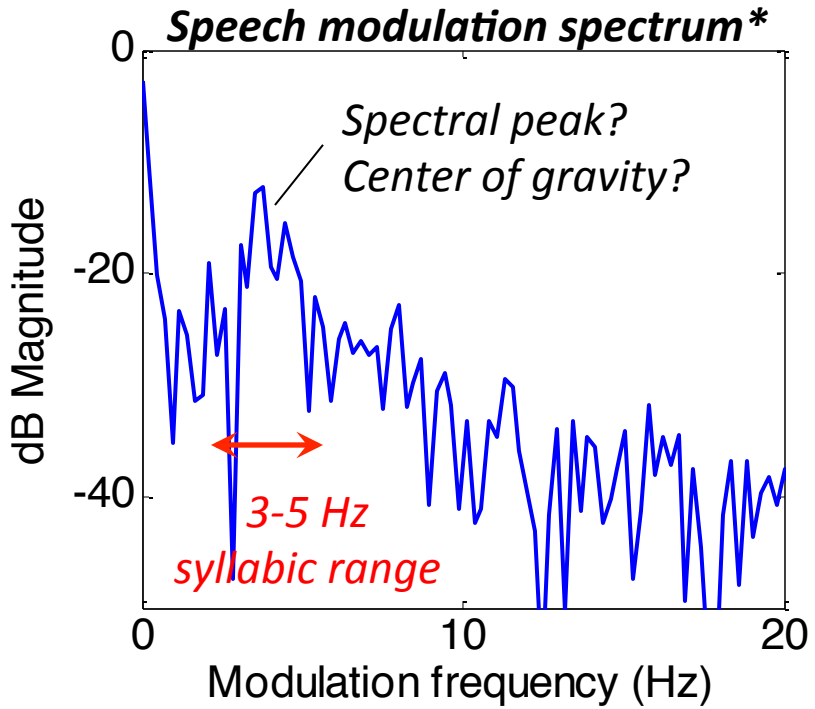




What's Wrong with Fourier?

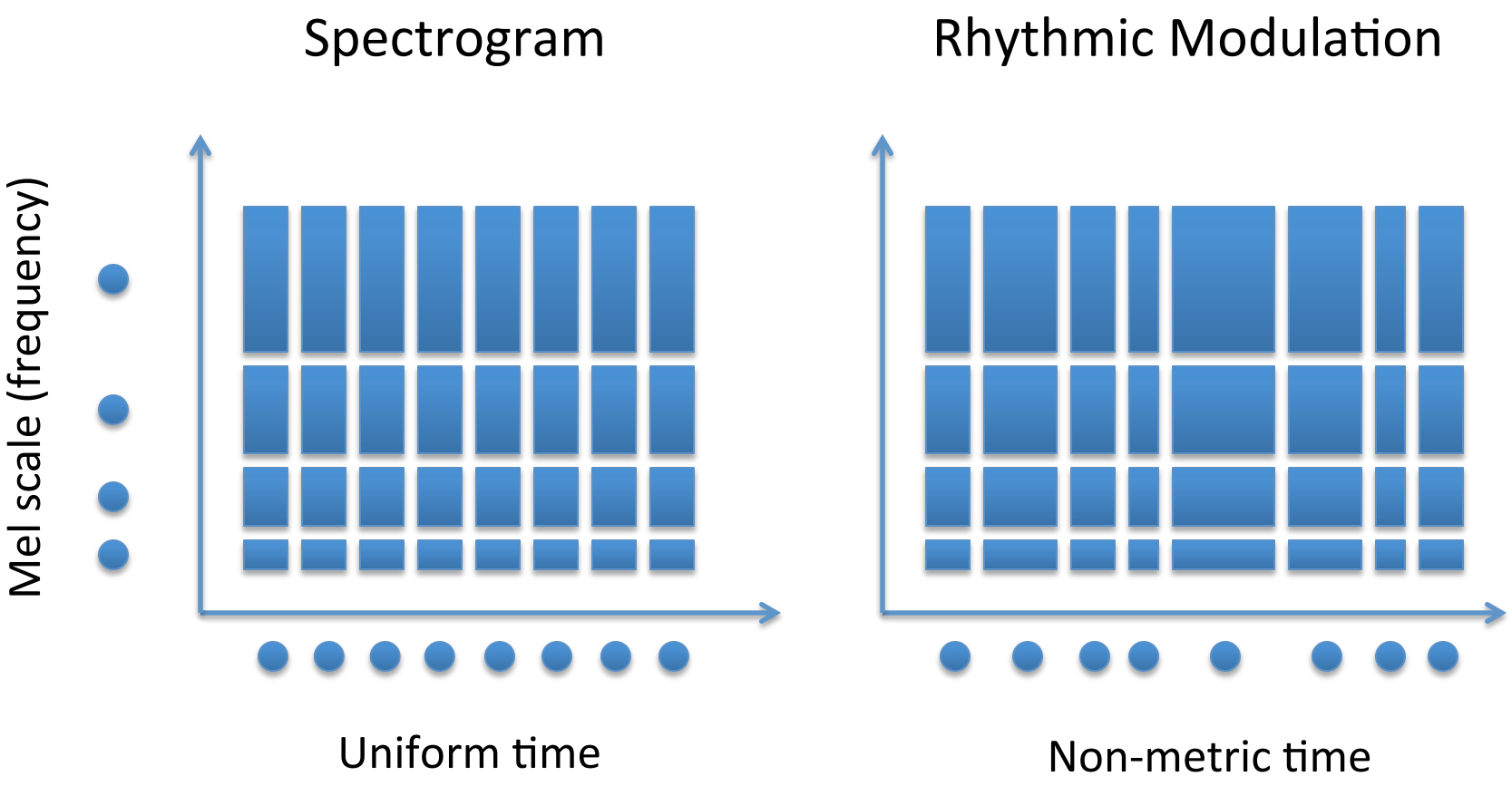
Speech is not periodic.





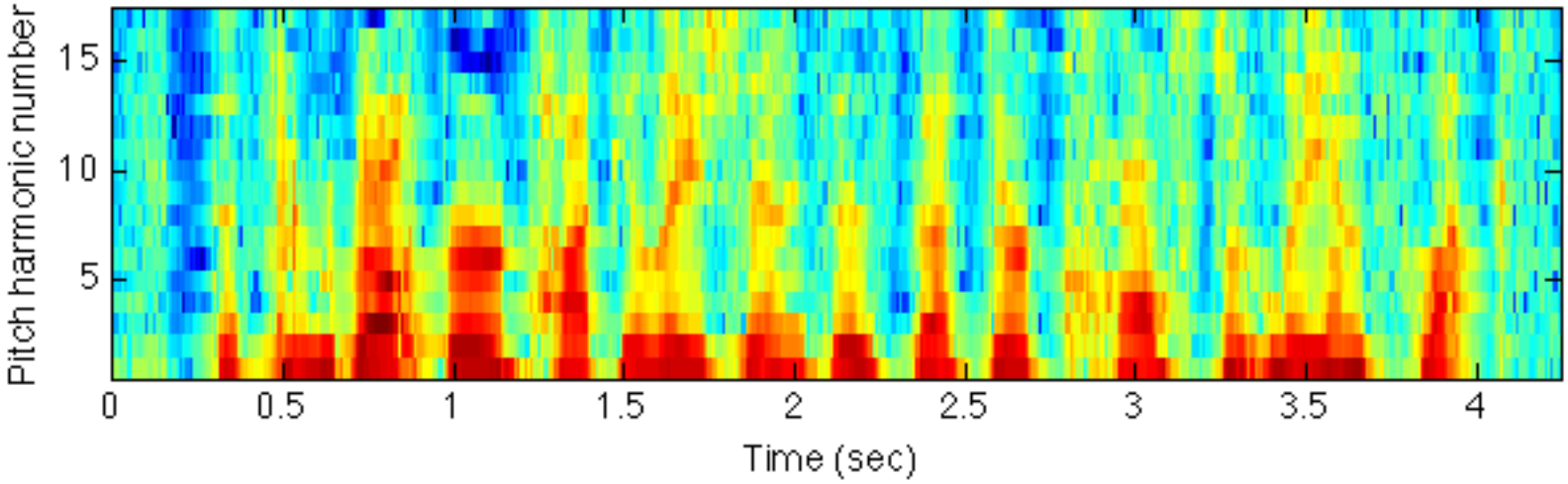
** Houtgast and Steeneken, 1985; Drullman, et al., 1994; Hermansky and Morgan, 1994*

Rhythm is Instead Event-Driven

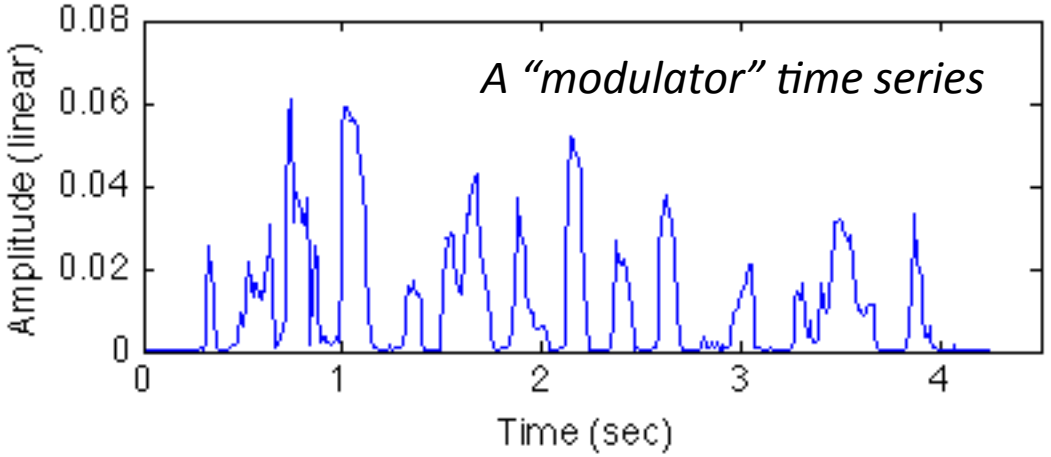


Rhythmic Demodulation (Part 1 of 3)

Smooth time-frequency representation (pitch-adaptive here):

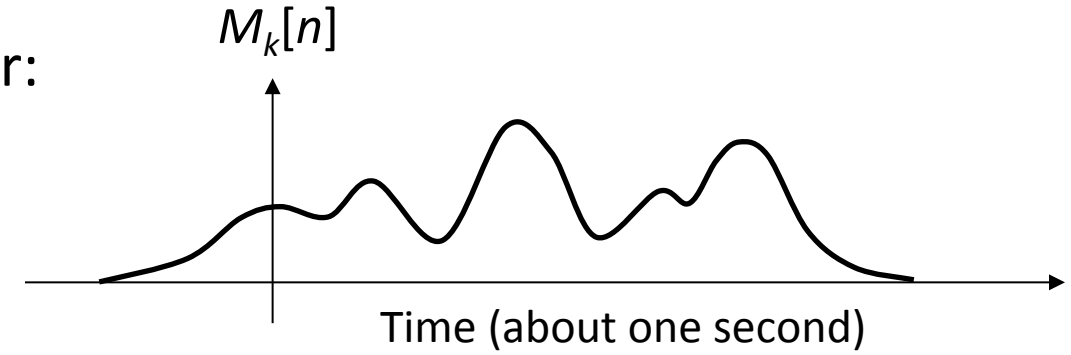


Take one row:

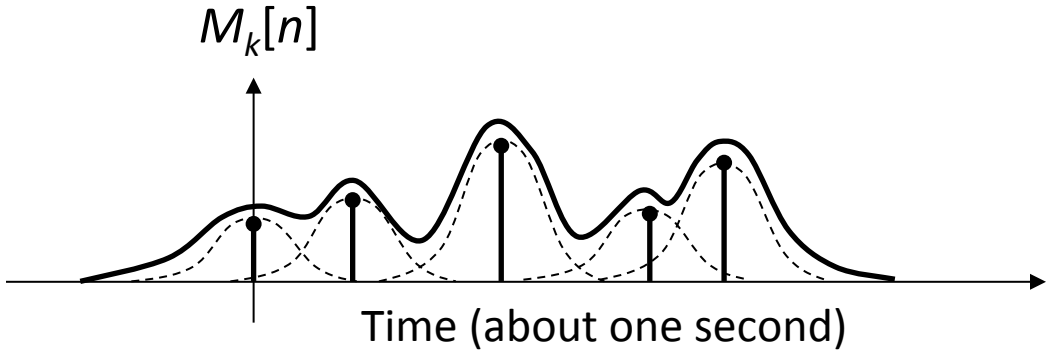


Rhythmic Demodulation (2 of 3)

Idealized modulator:

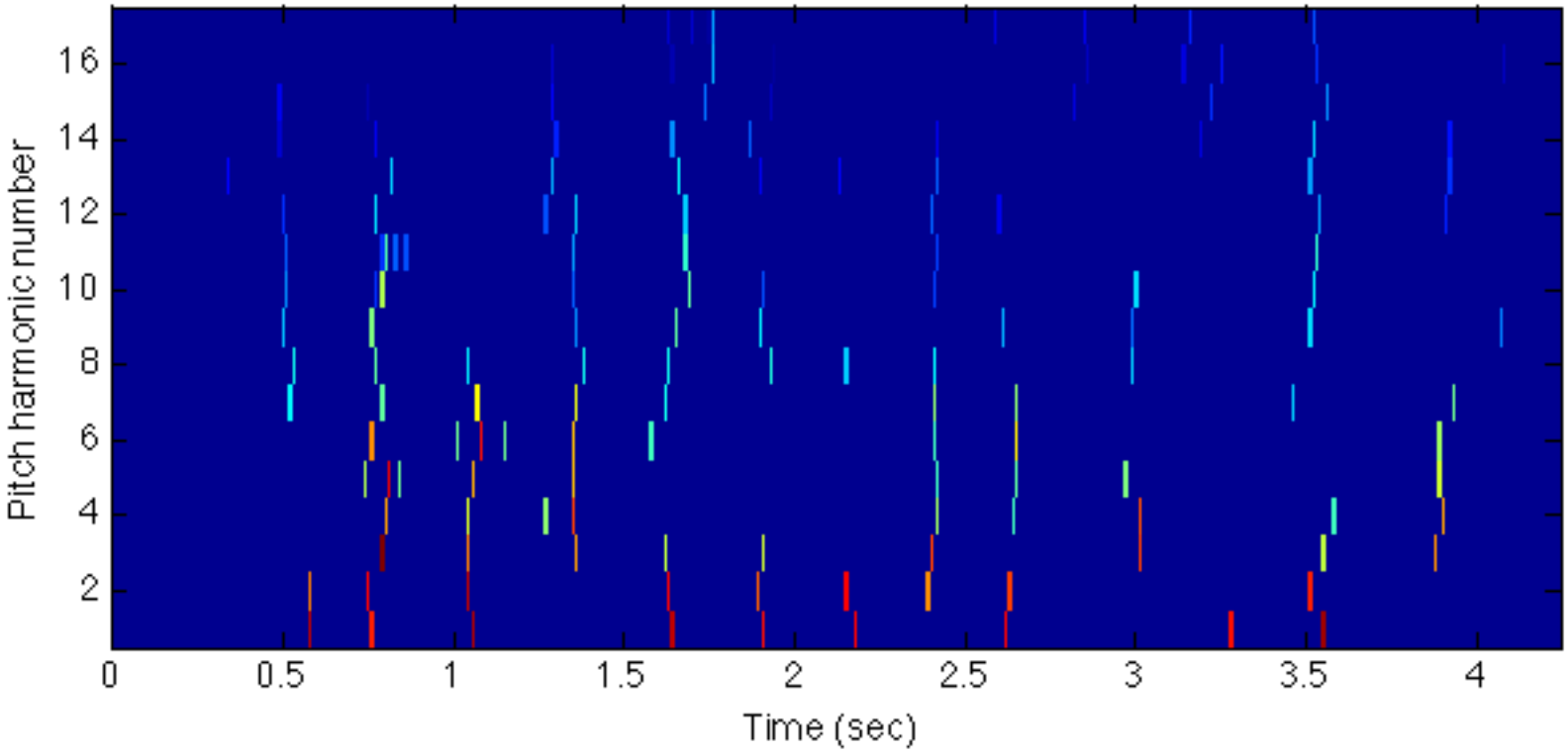


Rhythmic model with **sparse activations** and Gaussian signal basis (*"rhythmogram" approach, Lee and Todd, 2004*)



Rhythmic Demodulation (3 of 3)

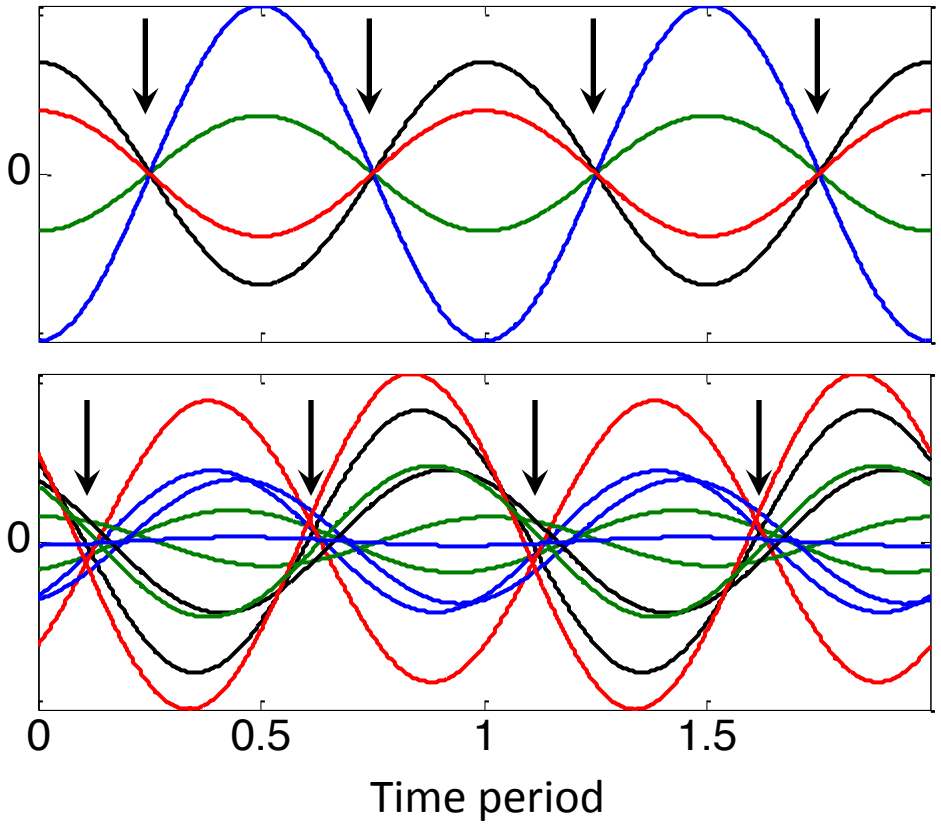
A systematic decoder based on matching pursuits (Mallat and Zhang, 1993), showing all activations after 20 iterations per row:



Principal Components of Rhythm

Rhythmic random process: $m[n] = \int a(\omega)\cos(\omega n) - b(\omega)\sin(\omega n)\, d\omega$

Gaussian random variables



$$\text{var}\{a\} = \text{var}\{b\}$$
$$E\{ab\} \neq 0$$

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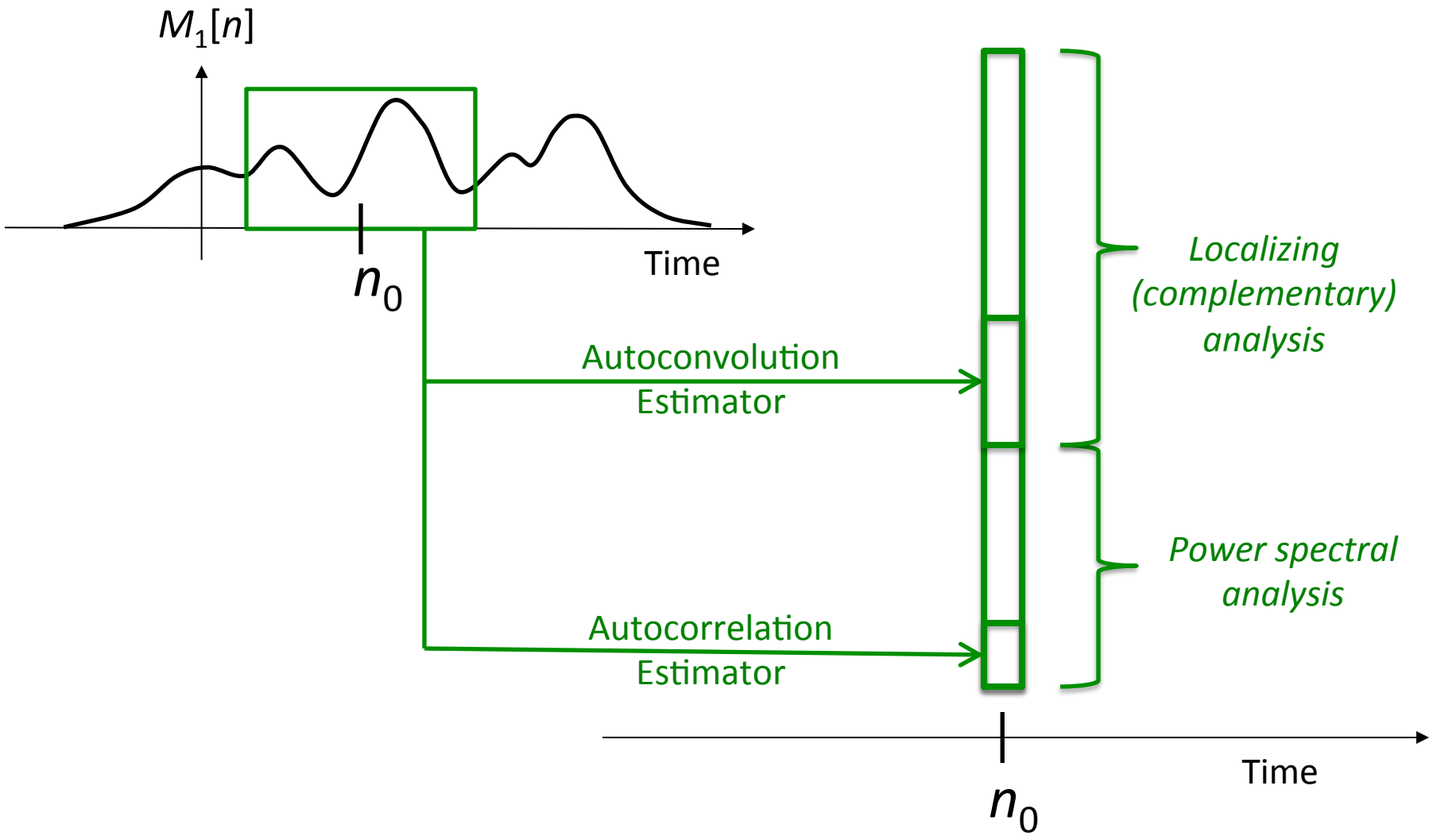
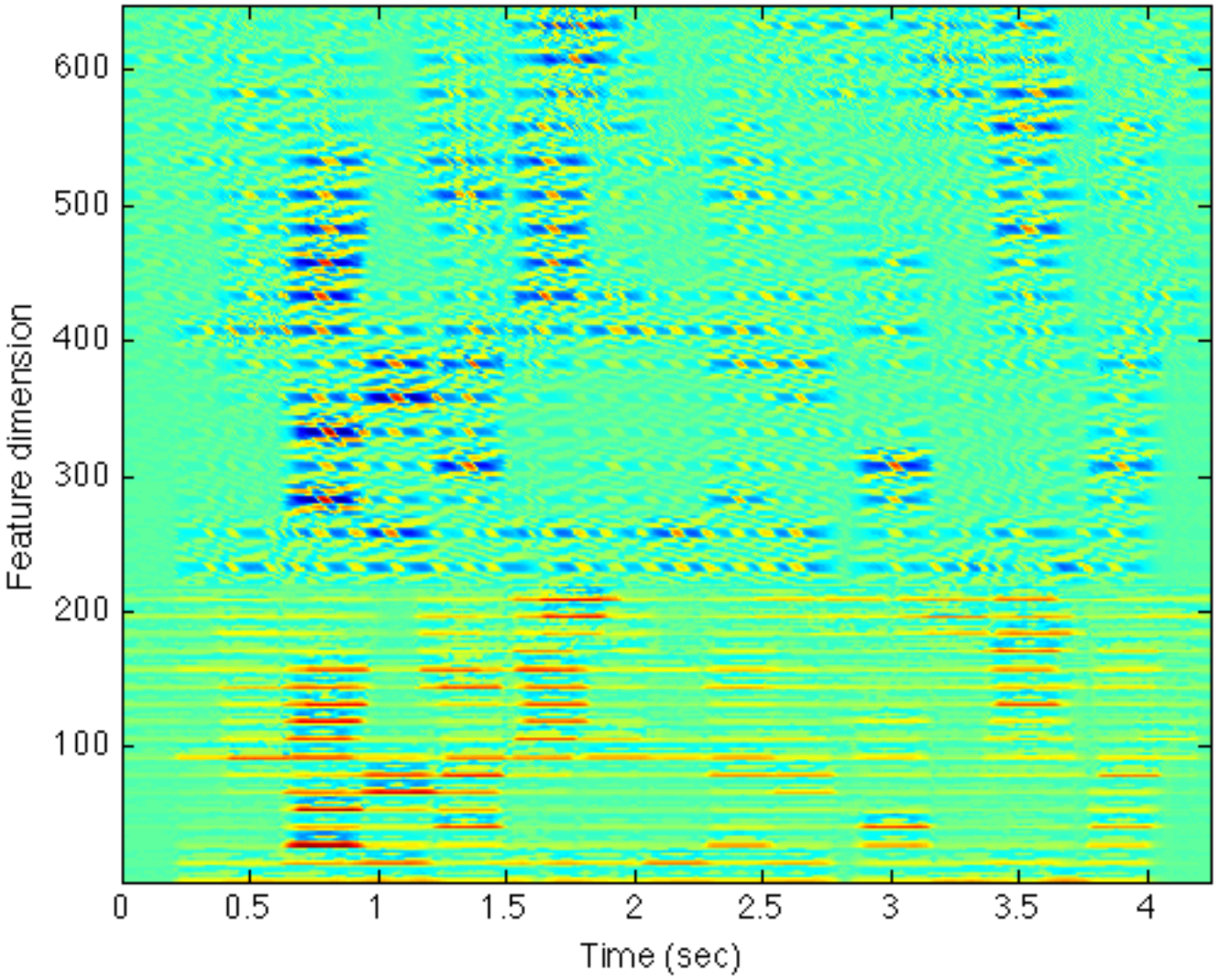
$$E\{ab\} \neq 0$$

Super-Vector Formation



Speech Super-Vector Example



Conclusion

Operational definition of syllabic rhythm:

- Sparse activations
- Non-uniform timing
- Non-periodic due to local variation

Localized deconvolution reveals underlying pattern of syllabic activations.

Possible speaker invariance?