Advances in the Analysis of Discrete Resonance Spectrograms

Using the DSR for Source Separation and Sequential Prediction

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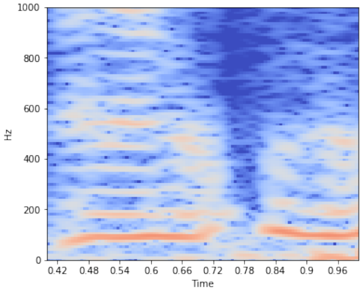
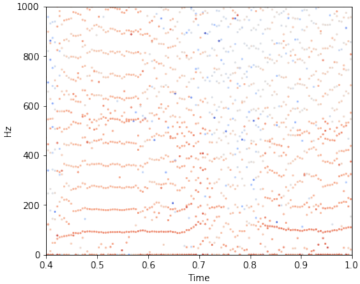
THE DISCRETE RESONANCE SPECTROGRAM (DRS)

Overview

- High resolution spectral analysis of audio signals
- Gives precise shape and location of spectral peaks
- Provides access to the content of audio signals





DRS ADVANTAGES AND APPLICATIONS

Target Applications

- Analysis of voice signals in industrial environments
- Vocal signature modelling
- Data compression

Advantages of the DRS

- Better resolution than FFT based methods
- Affords intelligent top-down signal processing
- Better integration with symbolic knowledge representation

CURRENT OBJECTIVES

Intelligent bottom-up pattern detection

- Parameter selection ✓
- Improve time resolution ✓
- Fundamental frequency (F0) tracking ✓
- Source detection and isolation
- Noise reduction

WORK TO DATE

Parameter selection ✓

An algorithm for automatically selecting parameters, reducing the need for tuning.

Improved time resolution ✓

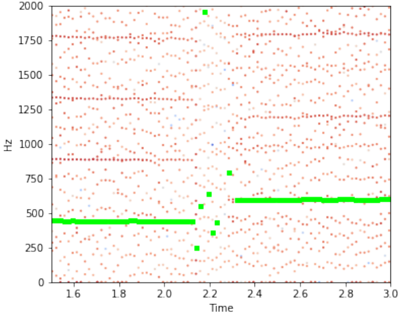
A segmentation algorithm which uses smooth sliding window envelopes.

F0 estimation ✓

An algorithm for tracking fundamental pitch (Geraint).

Original signal ▷
Basic analysis ▷
Enhanced analysis ▷

F0 tracking works well for simple harmonic sounds such as a flute.



IMMEDIATE NEXT STEPS

Phase and decay

Improve F0 tracking using phase and decay information

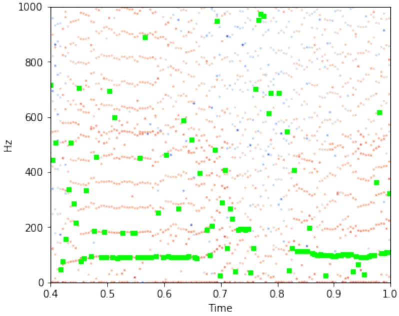
Inter-slice information

Use previous slice to inform analysis.

Source isolation

Use F0 information to detect and isolate individual sources.

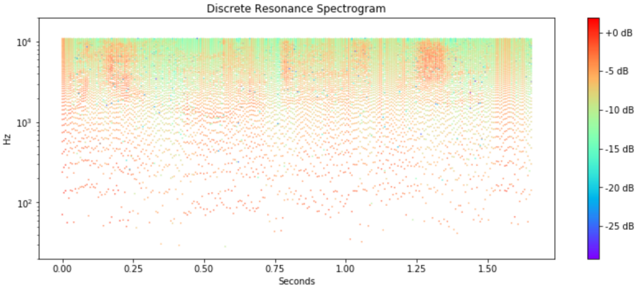
F0 tracking deteriorates for more complex sounds such as a voice.



SOURCE SEPARATION TO SEQUENTIAL PREDICTION

From Vertical to Horizontal Analysis

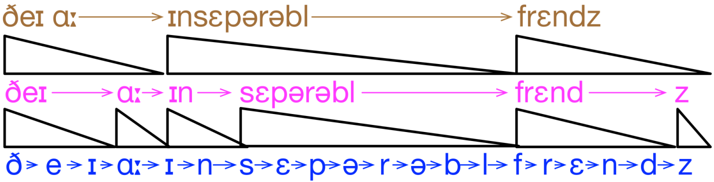
- Source separation looks at dependencies between frequencies **within a slice**, i.e. vertical analysis.
- Temporal correlations can be exploited to observe dependencies **between slices**, i.e. horizontal analysis.



BOUNDARY ENTROPY SEGMENTATION

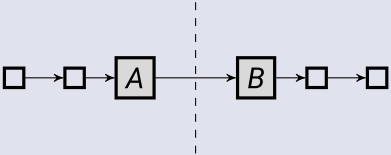
Boundary Entropy

- Online chunking according to **pairwise sequential** regularities in order to compress a stream of symbols
- **Unexpectedness**: current symbol is relatively more rare
- **Uncertainty**: current symbol has more options to follow



SEQUENCE VS NETWORK INTERPRETATION OF BES

Sequence Interpretation



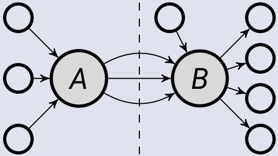
Information Content

$$h(x) = -\log p(x)$$

Entropy

$$H(x) = -\sum_{y \in Y} p(y|x) \log p(y|x)$$

Network Interpretation



In-Entropy

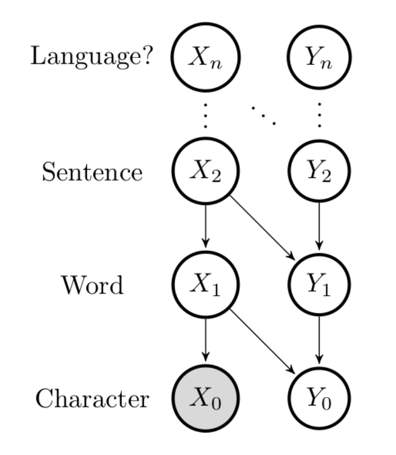
$$H_{in}(x) = -\sum_{y \in In(x)} p(x|y) \log p(x|y)$$

Out-Entropy

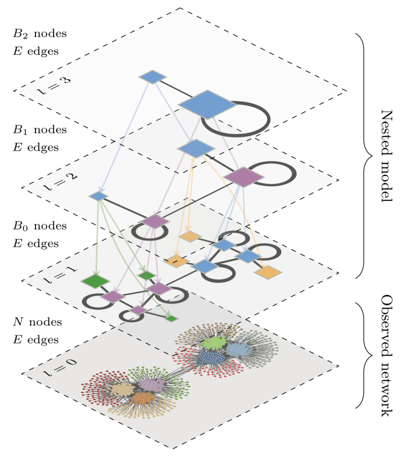
$$H_{out}(x) = -\sum_{y \in Out(x)} p(y|x) \log p(y|x)$$

HIERARCHICAL STRUCTURE AND DYNAMICS

Hierarchical Prediction



Hierarchical Structure



INFORMATION EFFICIENCY AND THE MDL PRINCIPLE

Memory Consolidation

- According to the **information efficiency** criterion of IDyOT, online boundary entropy segmentation is likely suboptimal
- **Offline memory consolidation** can fix some missteps that occurred online by lowering the total entropy of the model

Minimum Description Length Principle

- Σ (Description) = $\mathcal{L}$ (Model) + $\mathcal{S}$ (Data) (in bits)
- Least complex model that accurately describes the data
- Used for **model selection** in AIT and complex networks

PLACEMENT AND NEXT STEPS

Placement of Research

- **Online vs offline** community structure detection
- **Topological vs causal** structure inference in networks
- **Static vs temporal** system dynamics and link prediction

Immediate Next Steps

- Causal network topology **inference** and sequence prediction through boundary entropy segmentation
- Memory **consolidation** based on MDL principle for networks

APPLICATIONS AND FUTURE WORK

Applications

- Voice extraction in noisy industrial environments
- Pitch tracking and pitch to midi
- Straight up compression

Future Work

- Information-theoretic **categorization** of frequency space
- Robot route finding structure
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THANK YOU!

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Computational Creativity Lab