

# Advances in the Analysis of Discrete Resonance Spectrograms

Using the DSR for Source Separation and Sequential Prediction

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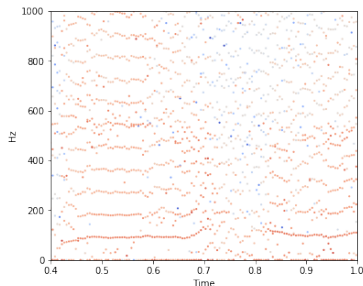
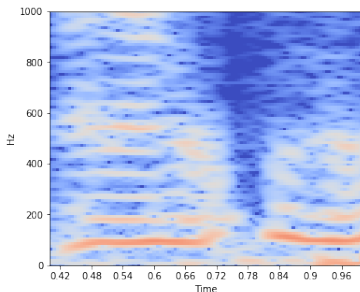


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# THE DISCRETE RESONANCE SPECTROGRAM (DRS)

## 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.

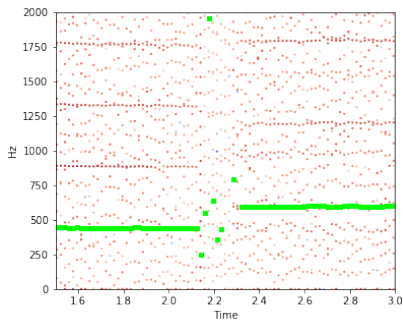
### Improved time resolution ✓

A segmentation algorithm which uses smooth sliding window envelopes.

### F0 estimation ✓

An algorithm for tracking fundamental pitch (Geraint).

Original signal ▷  
Basic analysis ▷  
Enhanced analysis ▷



## IMMEDIATE NEXT STEPS

### Phase and decay

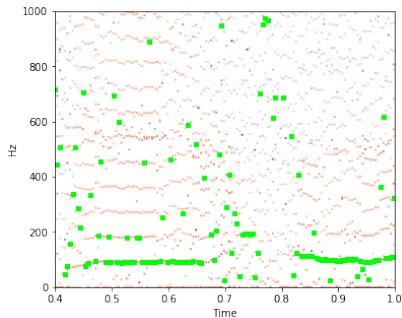
Improve F0 tracking using phase and decay information

### Inter-slice information

Use previous slice to inform analysis.

### Source isolation

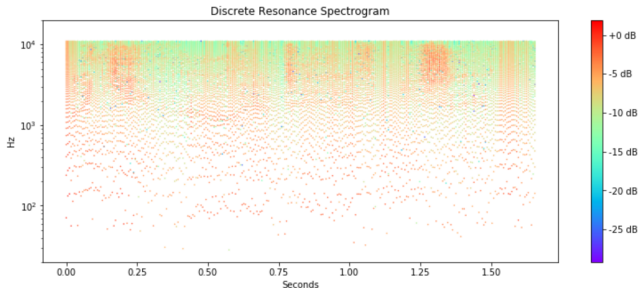
Use F0 information to detect and isolate individual sources.



# SOURCE SEPARATION TO SEQUENTIAL PREDICTION

## From Vertical to Horizontal Analysis

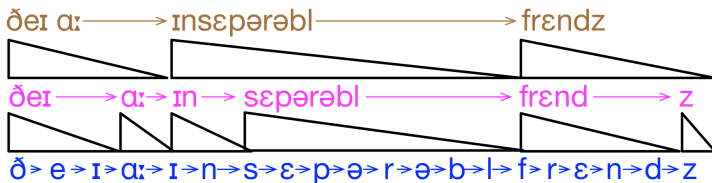
- ▶ Source separation looks at dependencies between frequencies **within a slice**, i.e. vertical analysis.
- ▶ Temporal correlations can be exploited to observe dependencies **between slices**, i.e. horizontal analysis.



# BOUNDARY ENTROPY SEGMENTATION

## Boundary Entropy

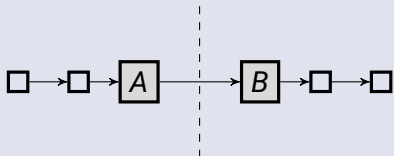
- ▶ Online chunking according to **pairwise sequential** regularities in order to compress a stream of symbols
- ▶ **Unexpectedness**: current symbol is relatively more rare
- ▶ **Uncertainty**: current symbol has more options to follow





# SEQUENCE VS NETWORK INTERPRETATION OF BES

## Sequence Interpretation



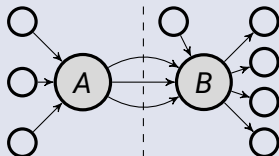
### Information Content

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

### Entropy

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

## Network Interpretation



### In-Entropy

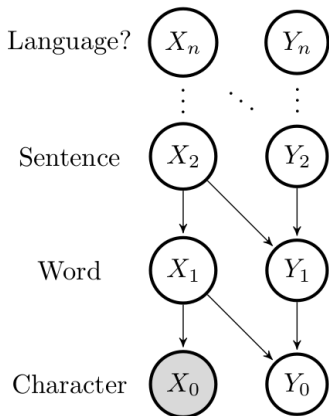
$$H_{in}(x) = -\sum_{y \in In(x)} p(x|y) \log p(x|y)$$

### Out-Entropy

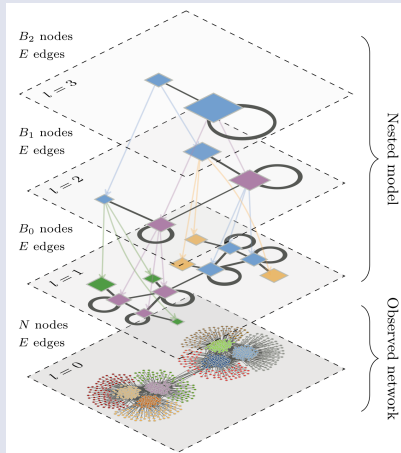
$$H_{out}(x) = -\sum_{y \in Out(x)} p(y|x) \log p(y|x)$$

# HIERARCHICAL STRUCTURE AND DYNAMICS

## Hierarchical Prediction



## Hierarchical Structure



## 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

- ▶  $\Sigma (\text{Description}) = \mathcal{L} (\text{Model}) + \mathcal{S} (\text{Data})$  (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

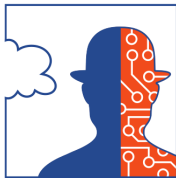
## Applications

- ▶ 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
- ▶

THANK YOU!



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