Identifying Polyphonic Patterns From Audio Recordings Using Music Segmentation Techniques

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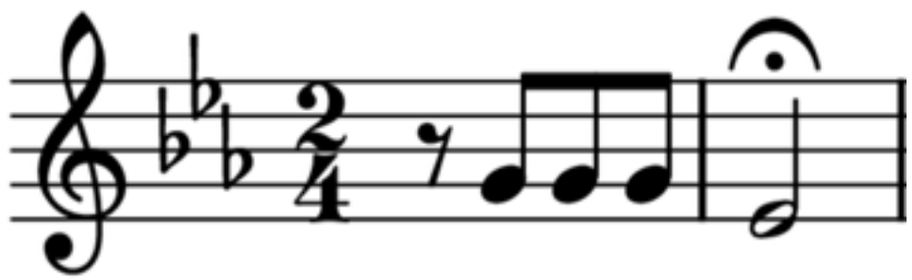
Pattern Discovery Task

- **Goal**: Identify all the patterns and their occurrences within a given piece.

- **Pattern**: musical idea (motive, theme, section) that repeats at least once.
  - Repetition might not be exact.

- As opposed to music segmentation:
  - Overlap between these patterns is accepted.
  - Patterns identified do not need to be contiguous.
  - Focus is primarily on harmony.



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Pattern Discovery Task

- Recently, more attention to this task:
  - New MIREX Pattern Discovery Task in 2013.
  - Publication of dataset to assess algorithms (JKU Dataset, Collins 2013).

- This task can be divided into four categories:
  - Symbolic Monophonic
  - Symbolic Polyphonic
  - Audio Monophonic
  - Audio Polyphonic

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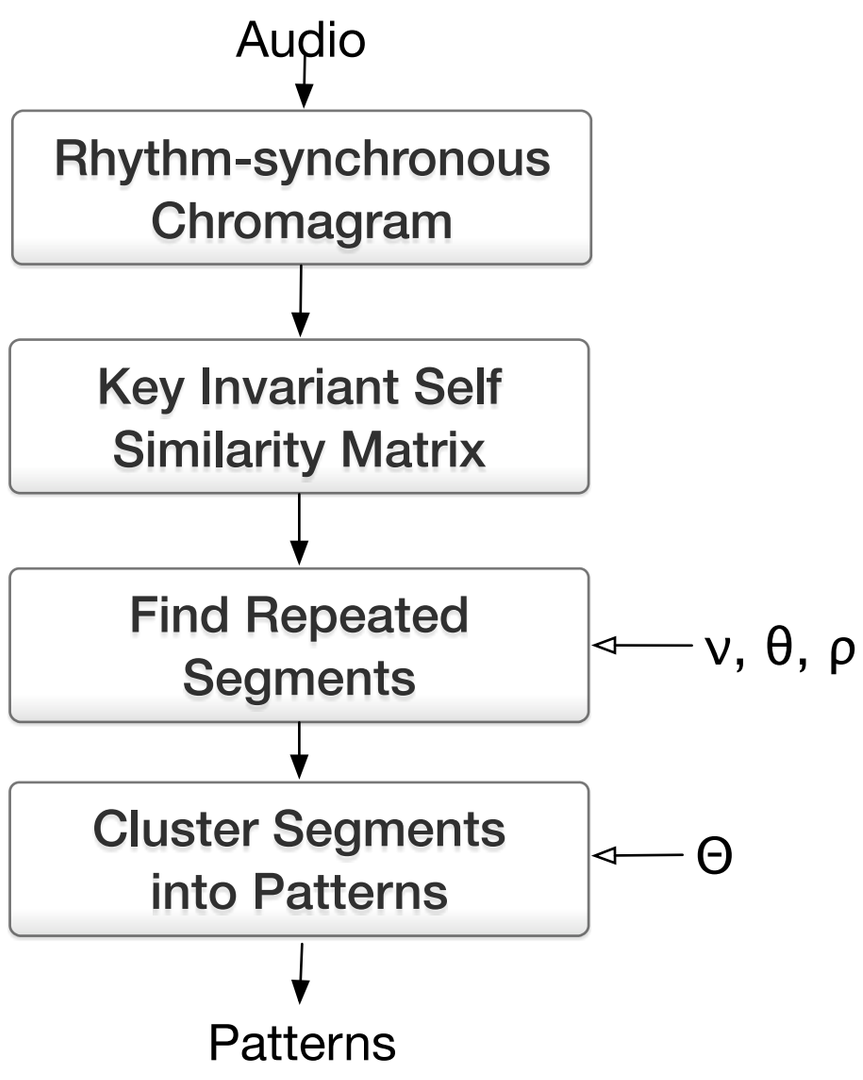
  - **Audio Polyphonic**

Proposed Approach

- **Idea:** Make use of music segmentation techniques to obtain the most repeated parts of a given audio track:
  - Segment boundaries sometimes characterized by the amount of **repetition**.

- Music segmentation task typically works on audio (instead of score).

Proposed Approach - Pipeline



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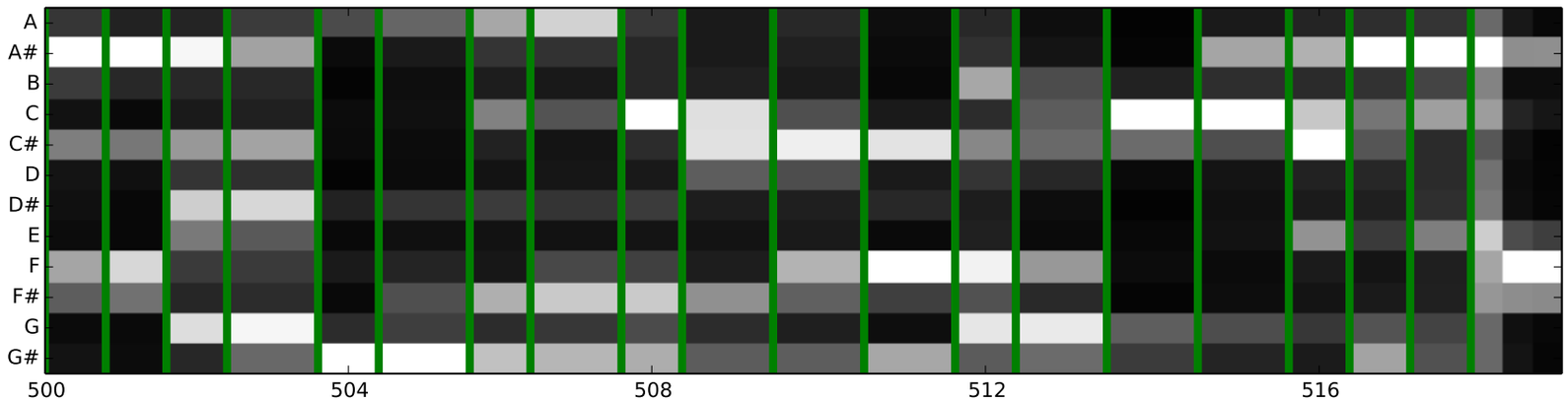
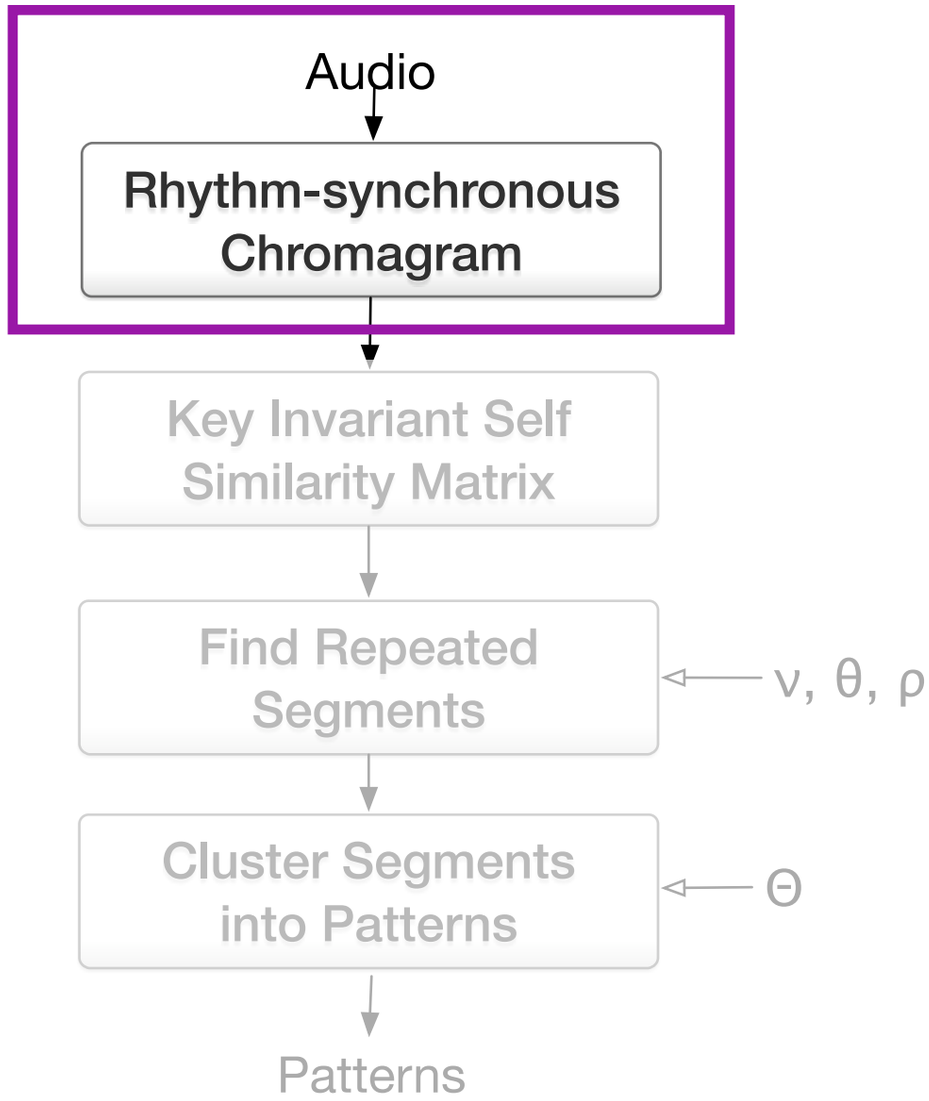
Rhythm-sync Chromagram

- Compute chromagram.
- Estimate beats (Ellis & Poliner, 2007):
  - Aggregate frames at more granular note level (N = 4 x Number of beats).
  - Resulting in rhythm-synchronous chromagram.





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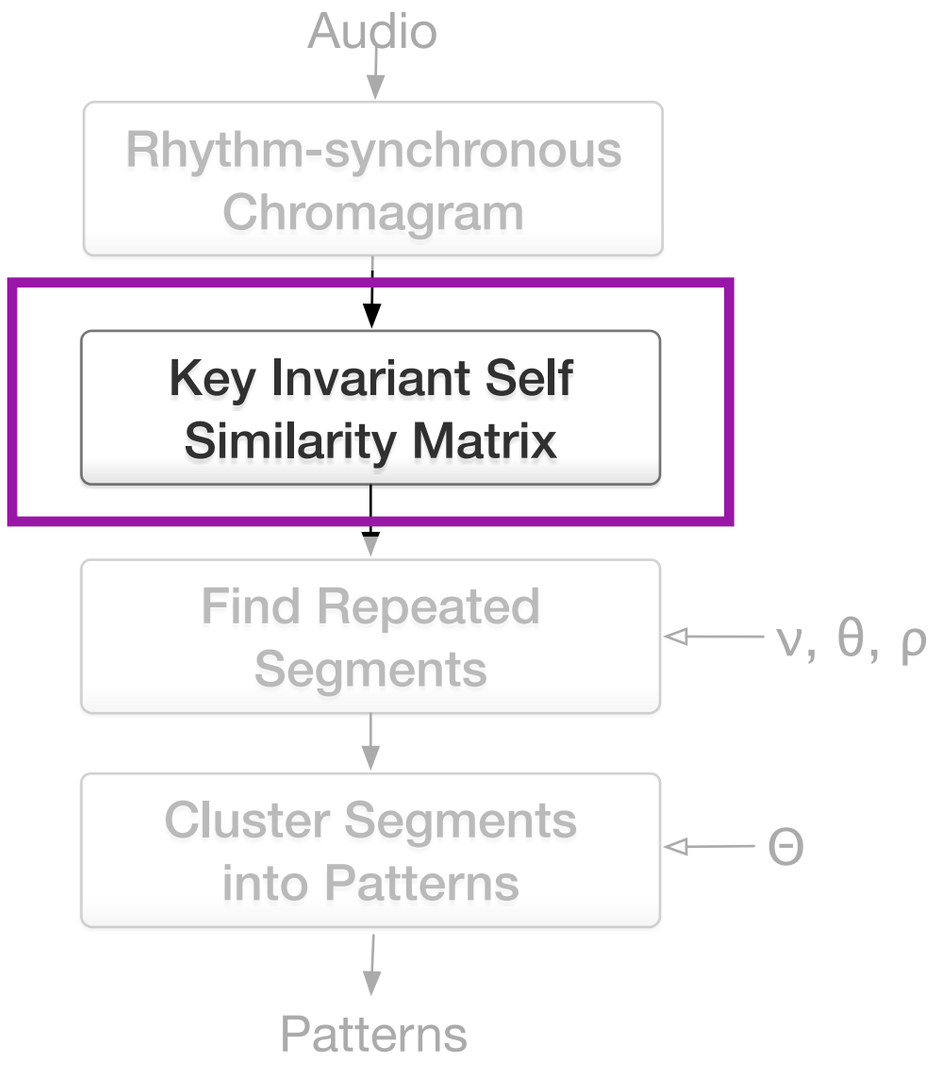
Self Similarity Matrix

- Compute Self Similarity Matrix from Chromagram using Euclidean distance.
- In order to identify patterns that might be key-transposed, we use the key invariant SSM method (Müller & Clausen 2007).



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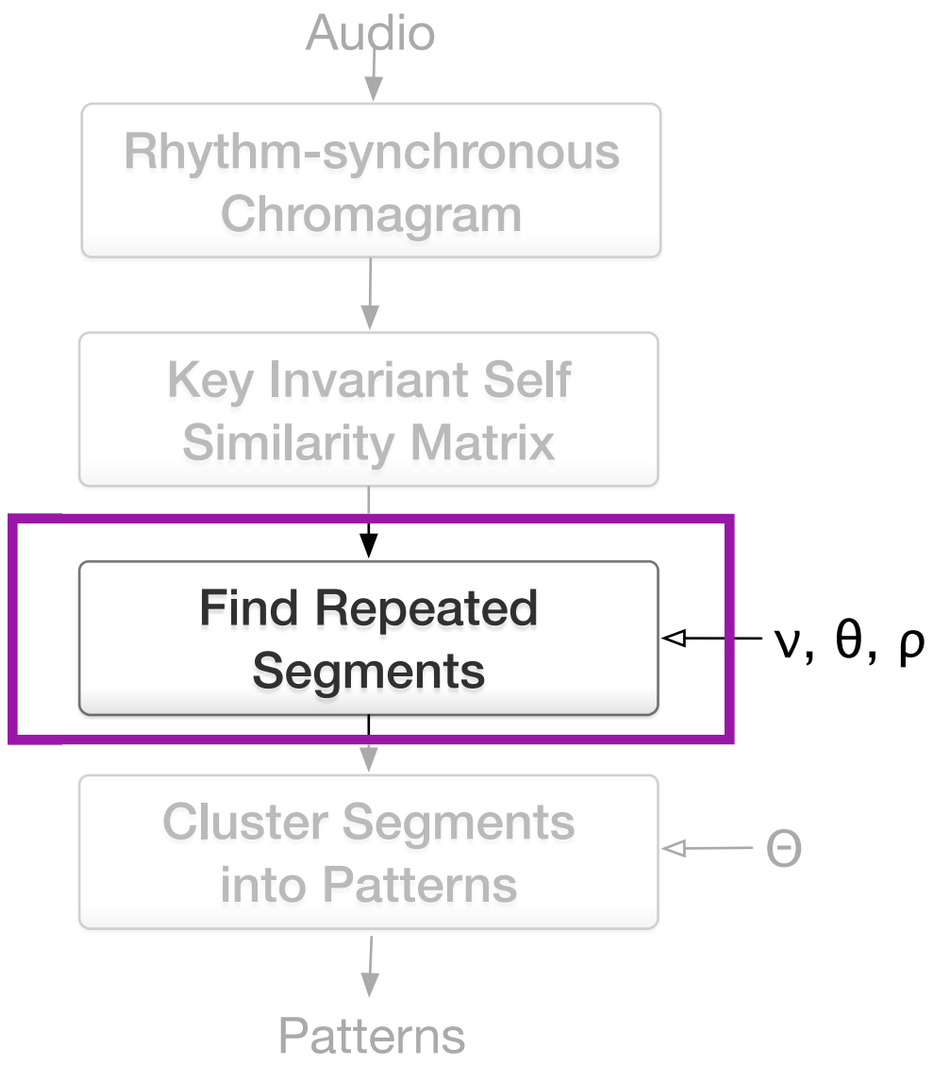
Establishing Patterns [1/4]

- Identify *all* possible repeated segments in the SSM.
- Independent of:
  - Duration.
  - Amount of overlap.
- Repeated segments appear in the SSM as diagonal "stripes" or **paths**.



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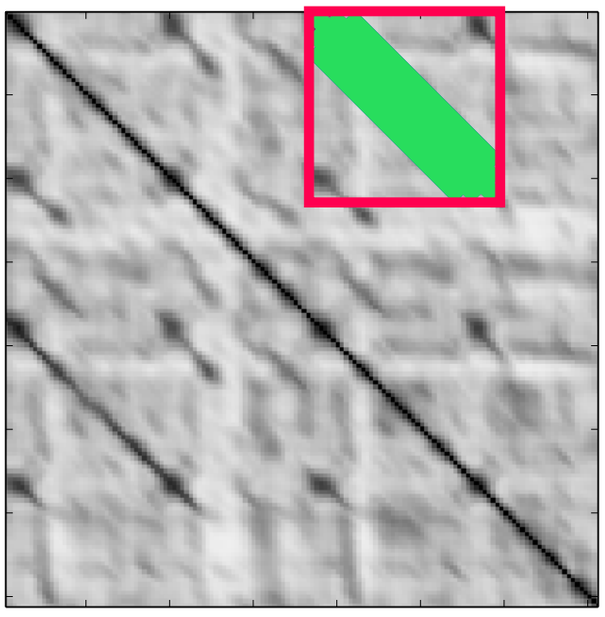
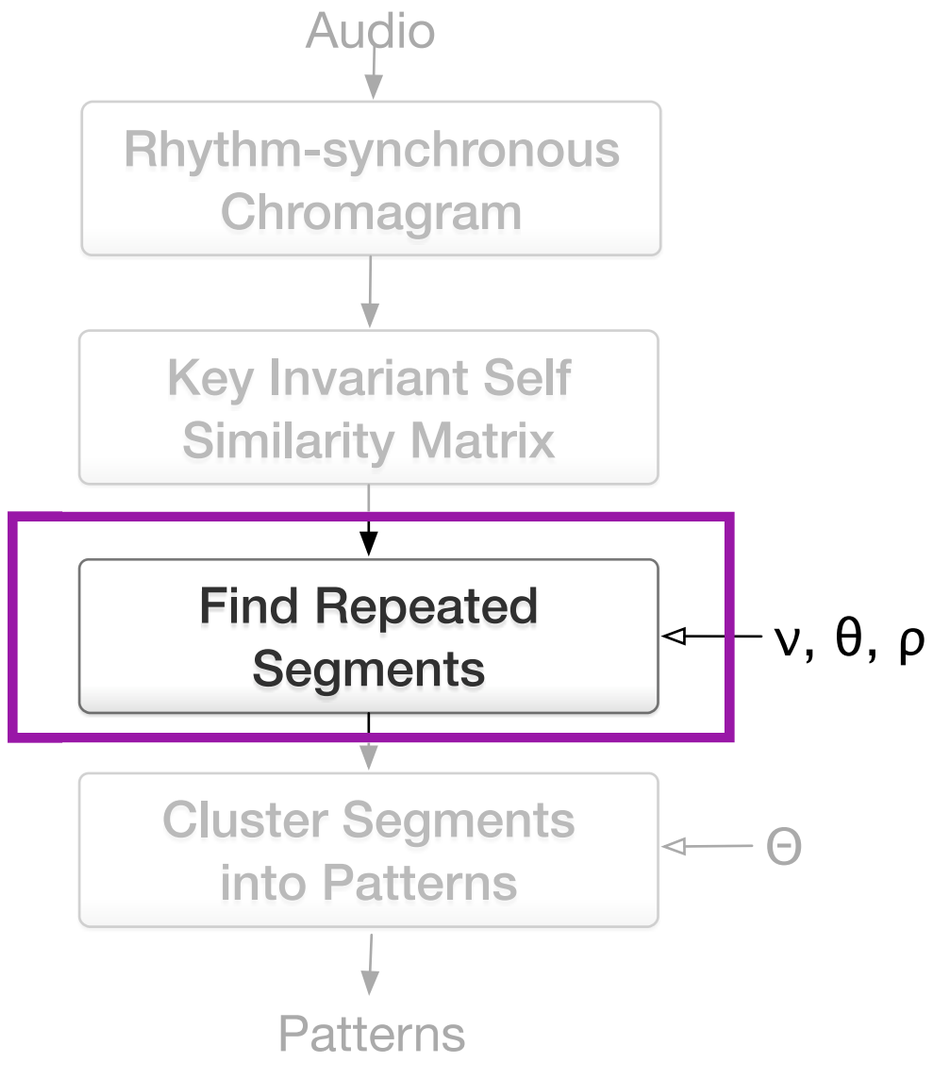
Establishing Patterns [2/4]

- For all possible path starting points:
  - Compute segment score σ:

$$\sigma(\rho) = \frac{\text{Sum over diagonal band} - \text{surrounding diagonals}}{\text{Sum over considered area}}$$





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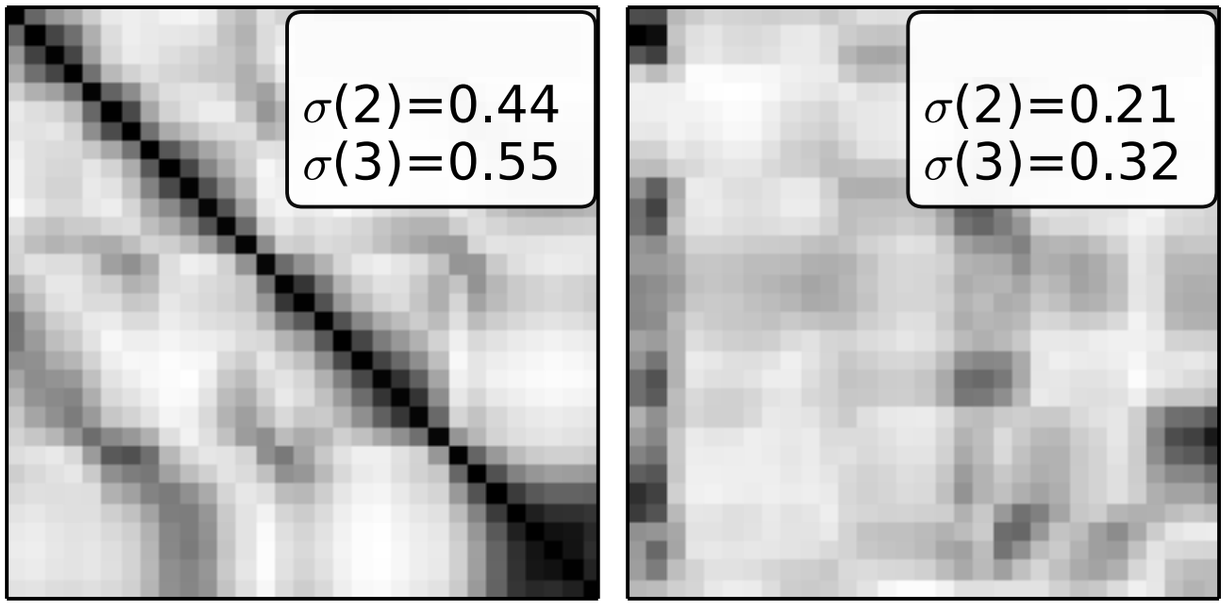
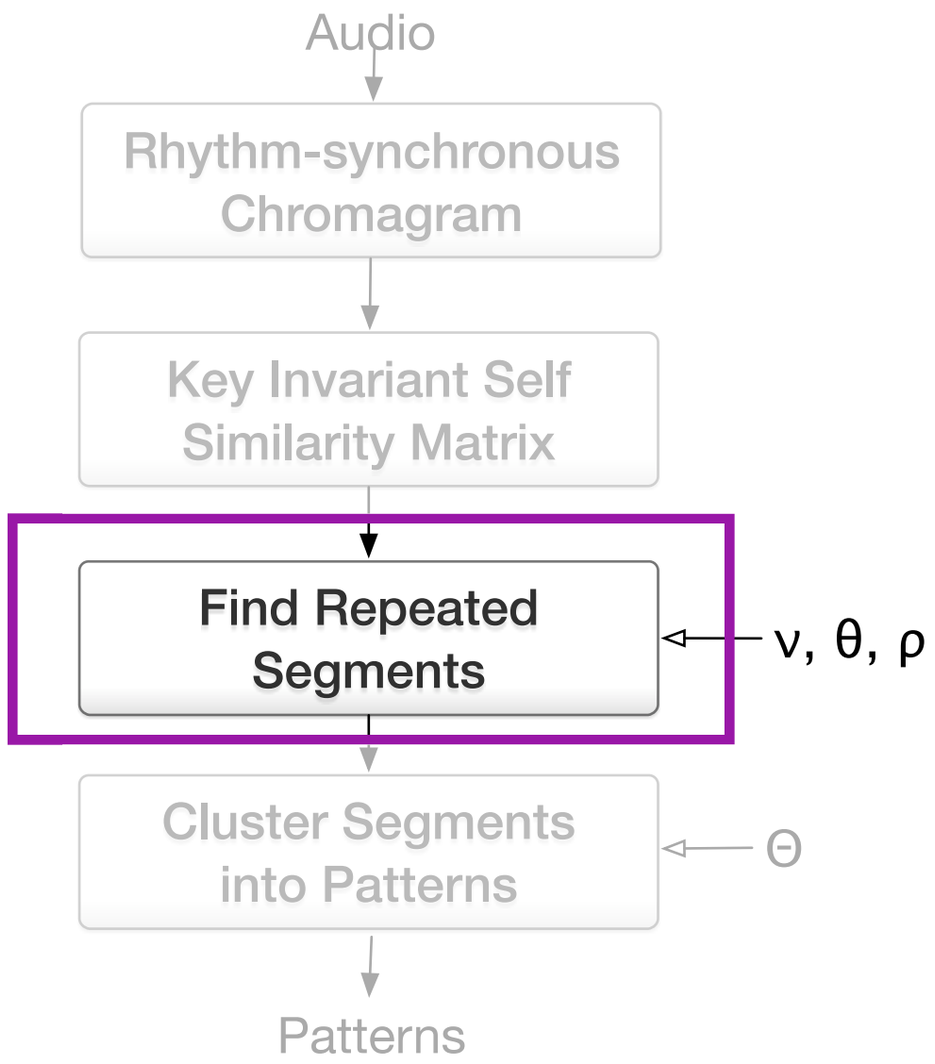
Establishing Patterns [3/4]

- Behavior of σ for various ρ (size of diagonal band):





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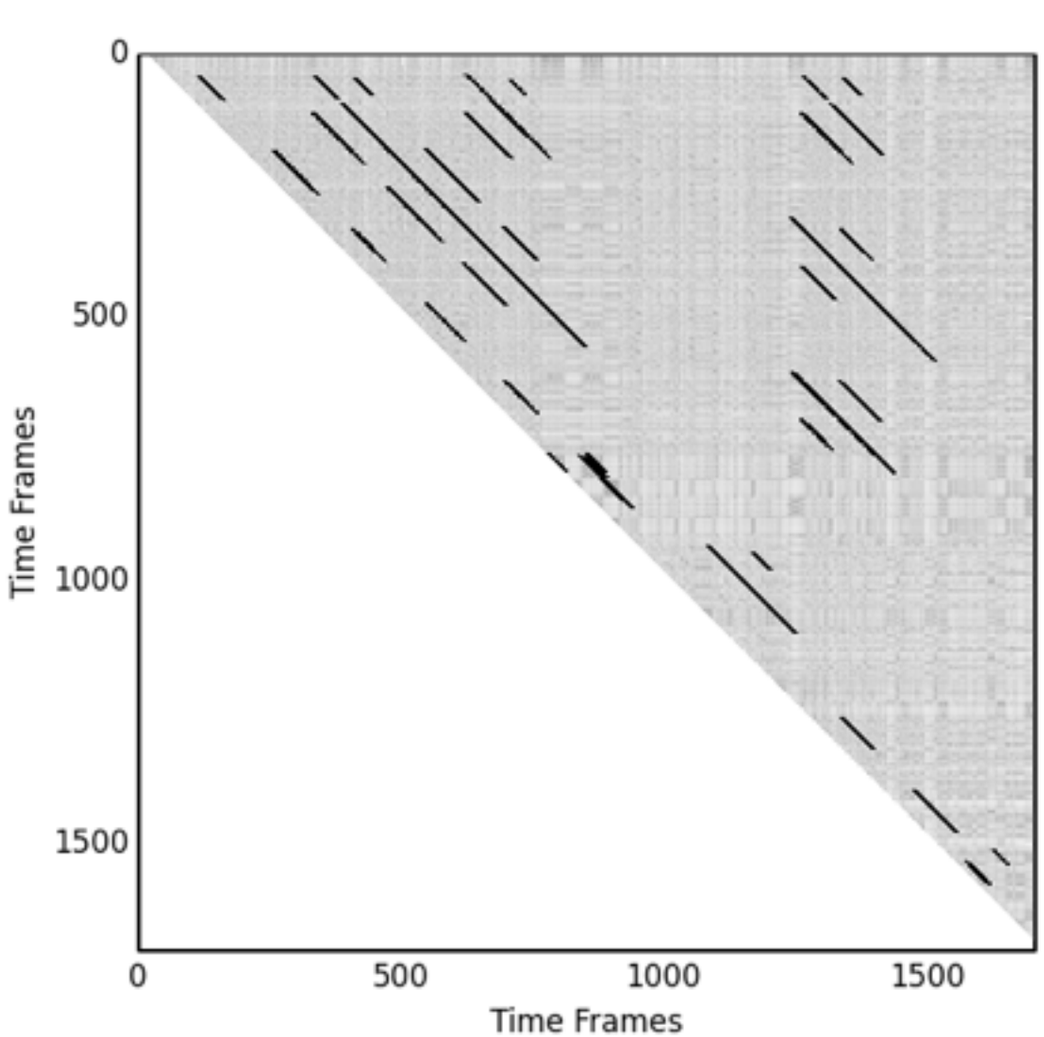
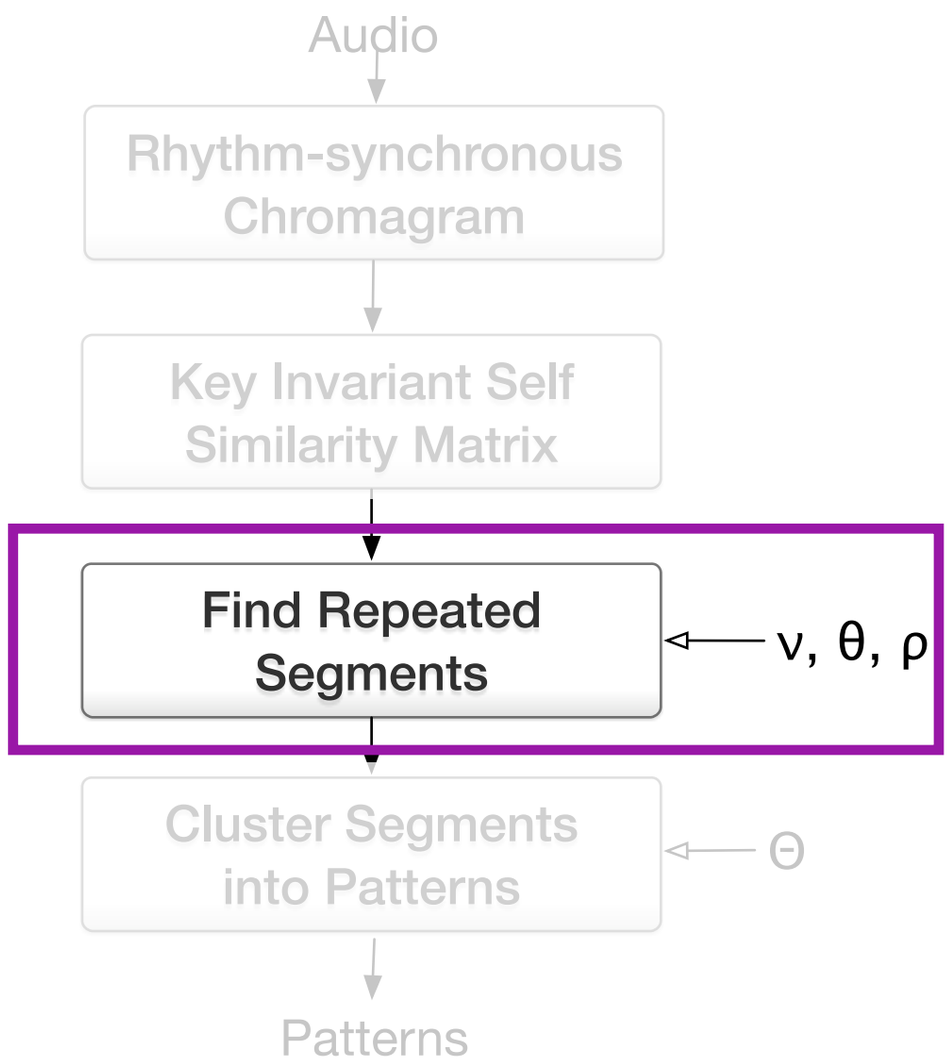
Establishing Patterns [4/4]

- For each possible starting position of a path in SSM:
  - Set minimum path length of **v**.
  - While **σ > θ**:
    - Path found.
    - Increment path length
    - Recompute **σ**
  - If path found:
    - Store it and zero out path in matrix.





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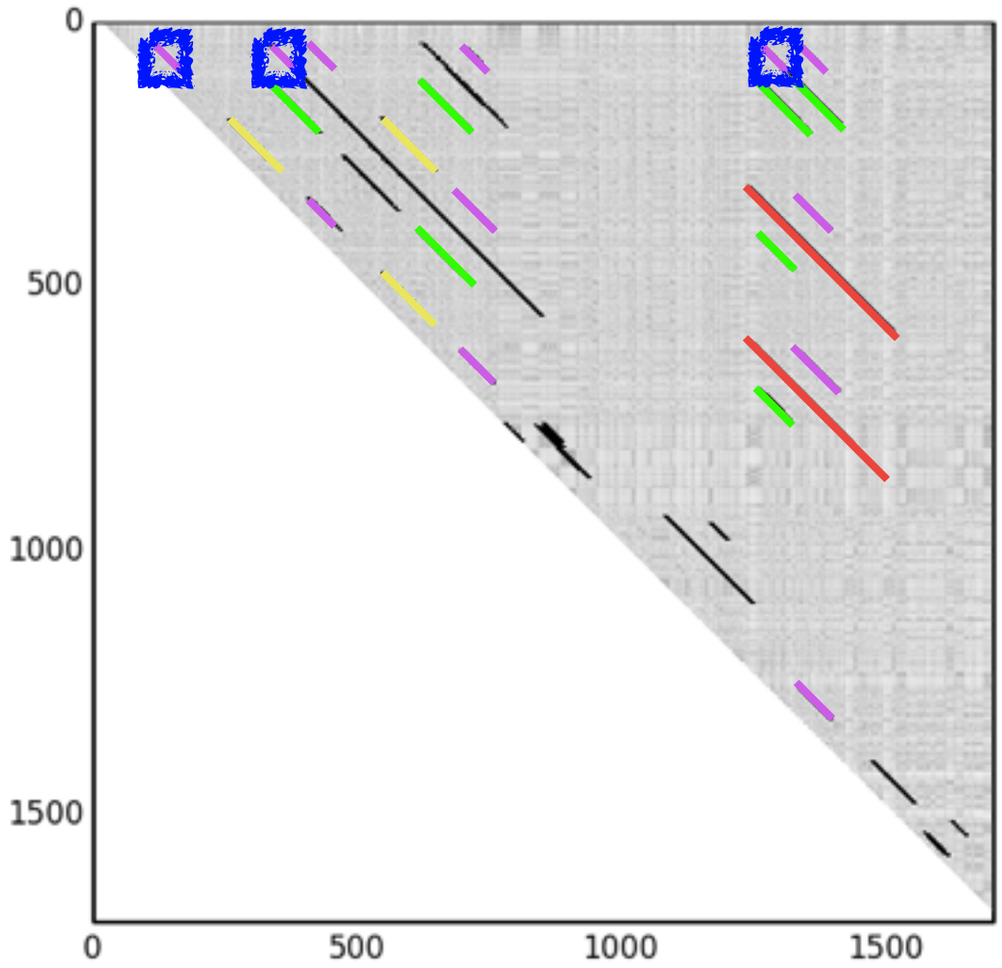
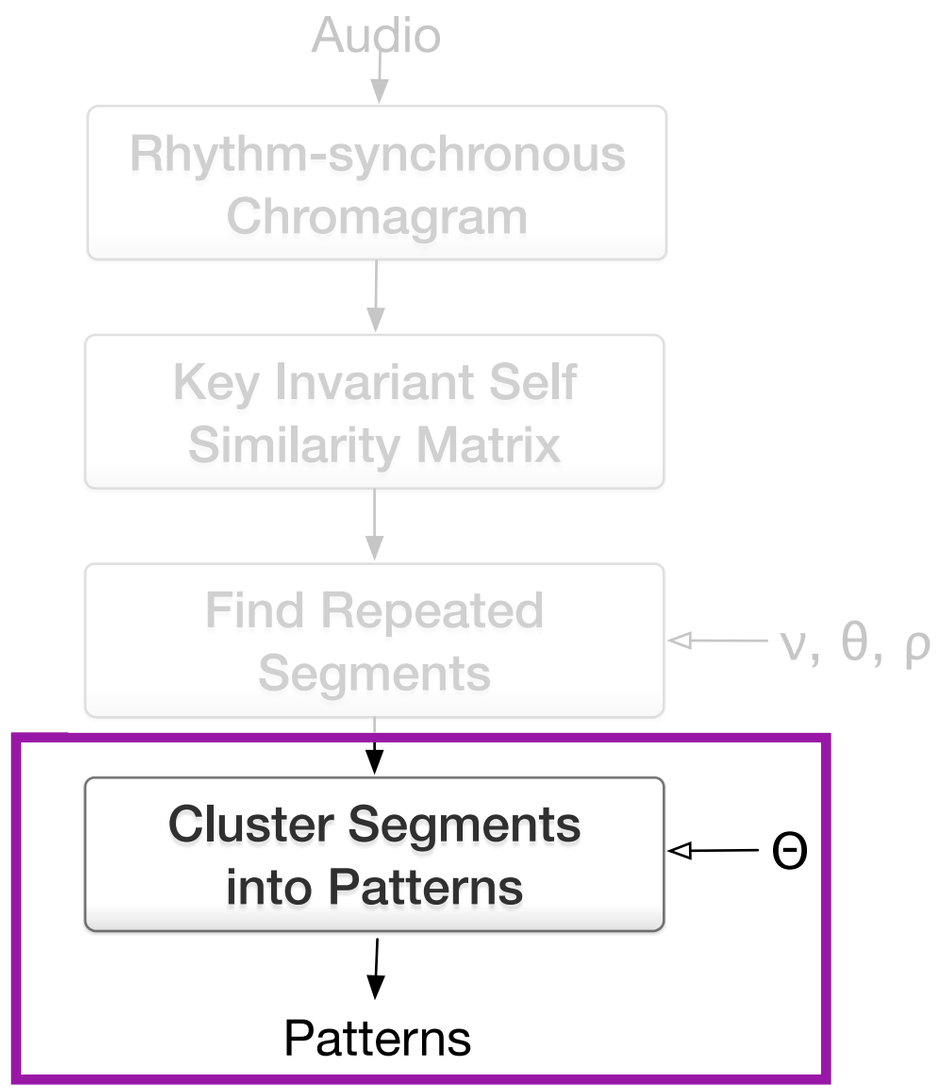
Identifying Occurrences

- Cluster two paths together if:
  - For at least in one of the two dimensions in SSM:
    - Both start and end times are within a time window **Θ**.





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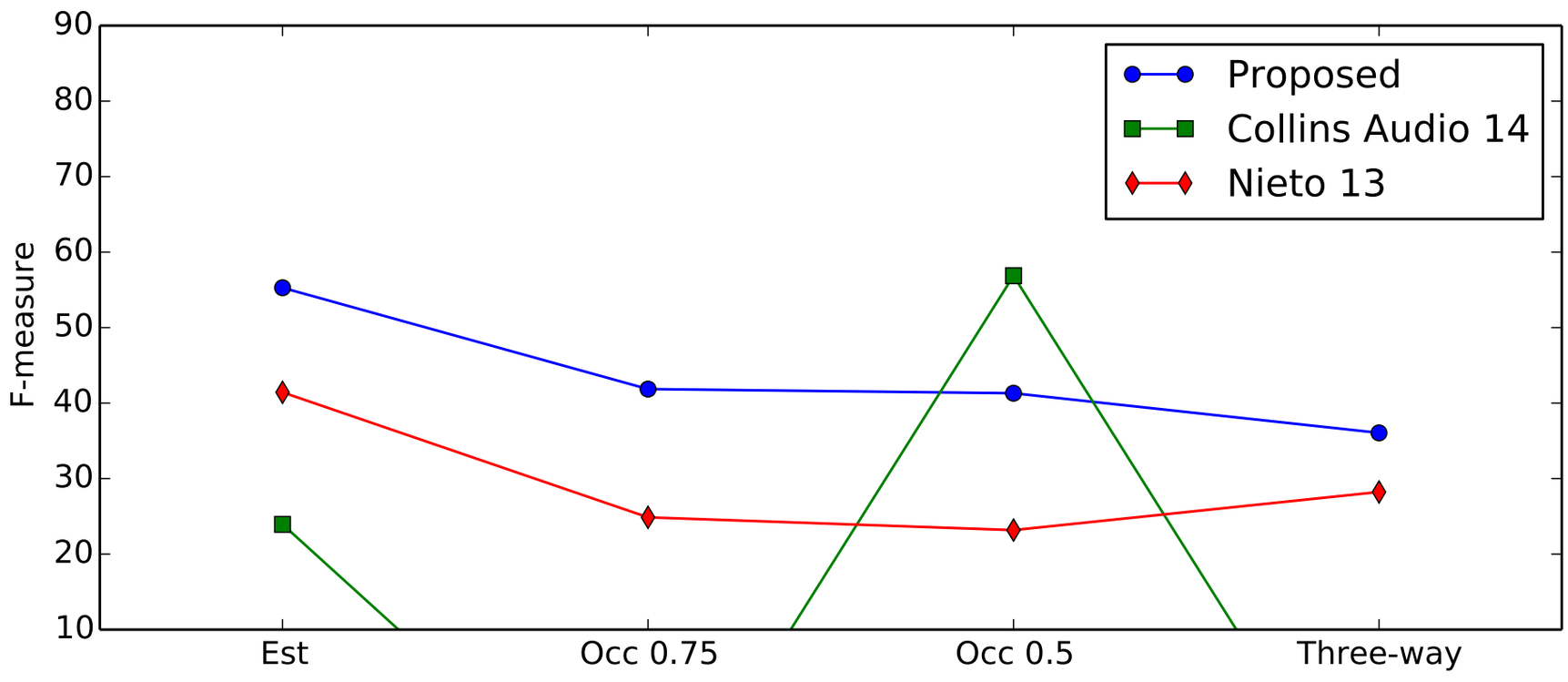
Proposed Approach

- Easy to adapt this algorithm to the other categories of this task:
  - Symbolic Monophonic
  - Symbolic Polyphonic
  - Audio Monophonic

Results

- Evaluated on the JKU Development Dataset:
  - 5 classical pieces annotated by multiple music experts.
  - Deadpan audio (synthesized from symbolic data).
- Using the same metrics as in MIREX.



Audio-Polyphonic Algorithms

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Computed using **`mir_eval`**

It is so good! :-)

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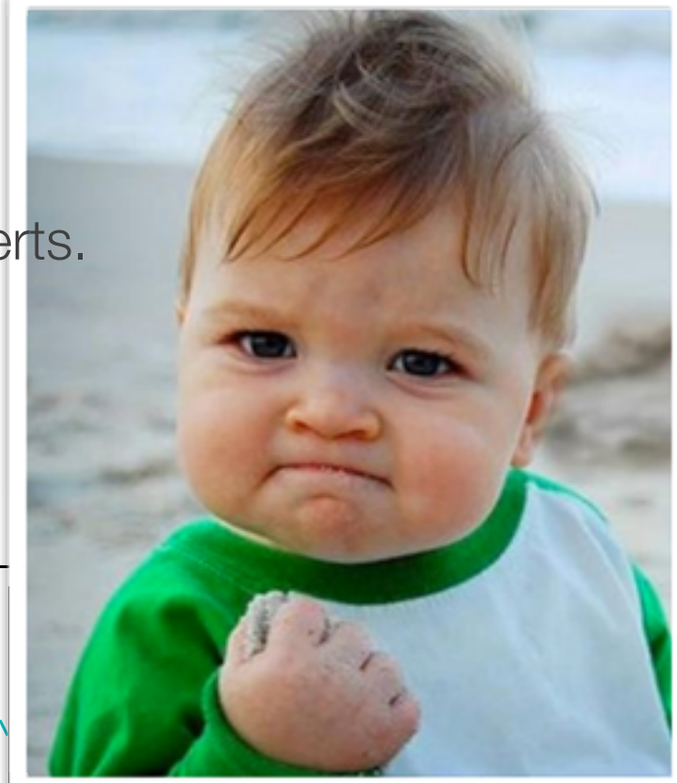

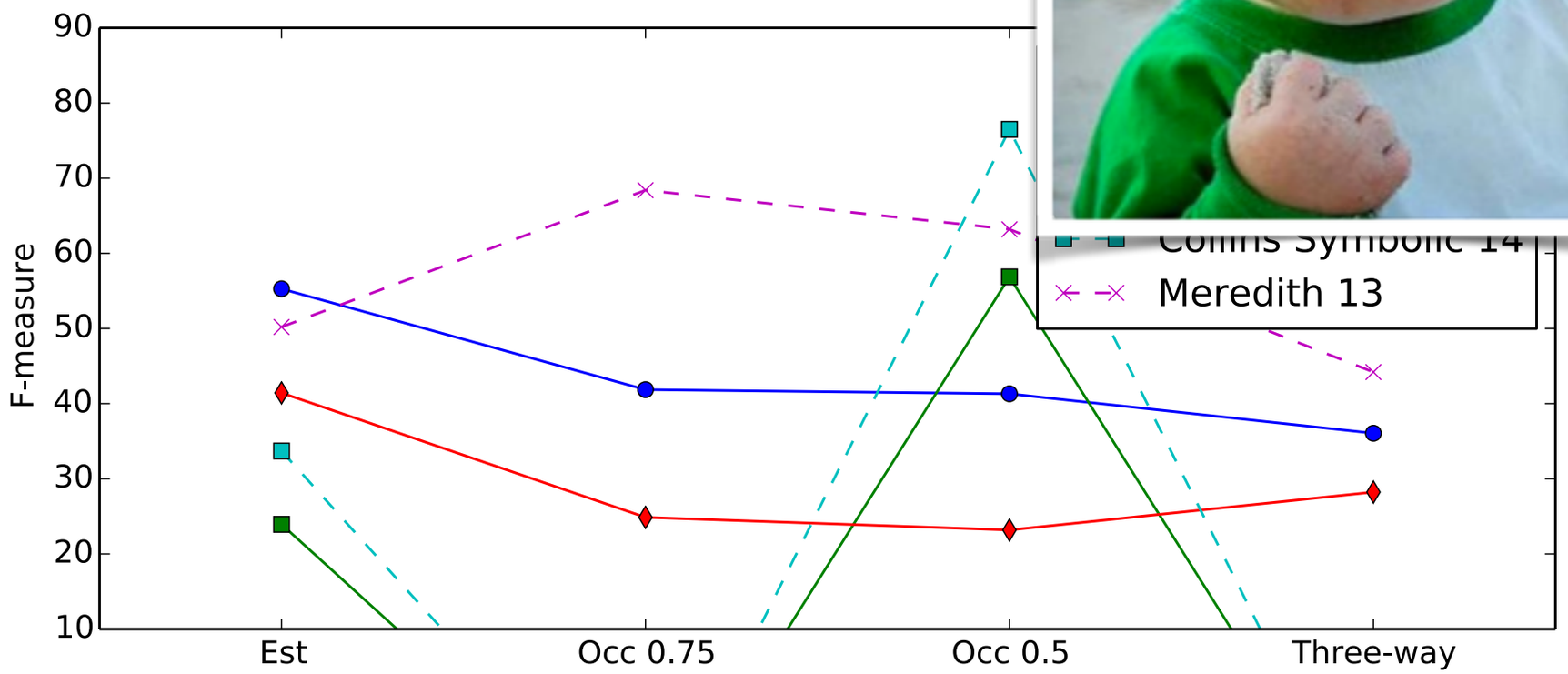

Polyphonic Algorithms

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Conclusions and Discussion

- Presented a novel algorithm to identify polyphonic patterns from audio.
- This approach is state of the art in establishing patterns using audio as input (but we are the only ones in MIREX!).
- Music segmentation techniques are useful in this task.
  - Will these two tasks eventually converge?

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Open Source

- Replicate (and improve :-)) these results!
- All source code in Python in:
  - https://github.com/urinieto/MotivesExtractor

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Thanks!

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