

# A comparison of similarity measures for musical pattern matching

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# Thanks to

Tunes & Tales,  
Meertens Institute



Music Cognition Group,  
Amsterdam



# The study

# The study

- Compared six similarity measures

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- Compared six similarity measures
- Thresholds

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- Compared six similarity measures
- Thresholds
- Pattern length

# Results

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- String comparison outperforms difference measures



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- Measures which view melodies as curves only become successful for patterns  $\geq 6$  notes

# Motivation

# Studying melodic stability

NLB71441

NLB71666

NLB72306

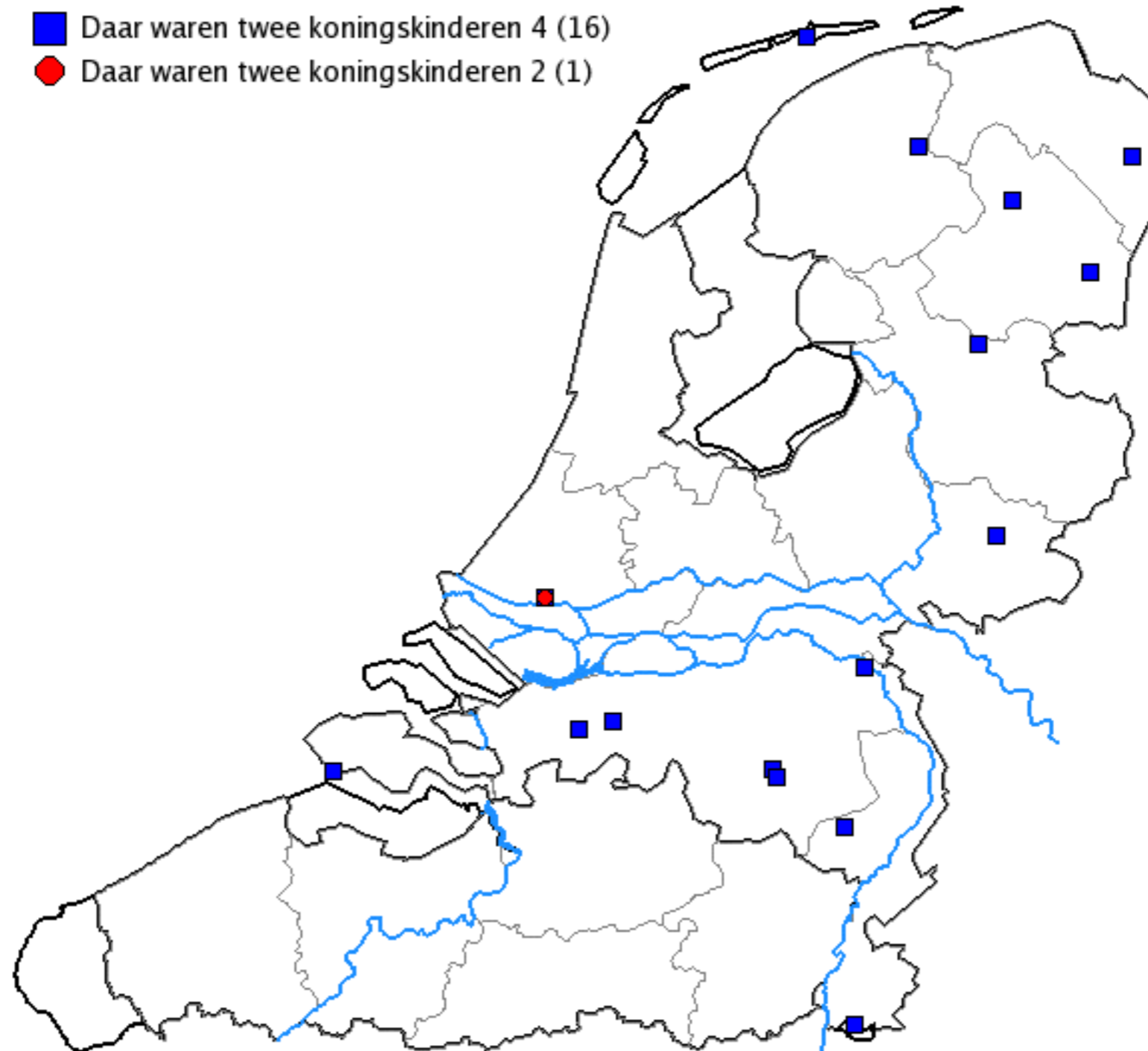
NLB72311

NLB73150

The image displays five musical staves, each representing a different exercise for studying melodic stability. Each staff begins with a treble clef and a common time signature (C). The exercises are labeled as follows:

- NLB71441:** The first three notes (G4, A4, B4) are highlighted in green.
- NLB71666:** The first three notes (G4, A4, B4) are highlighted in green.
- NLB72306:** The first three notes (G4, A4, B4) are highlighted in green.
- NLB72311:** The first three notes (G4, A4, B4) are highlighted in green.
- NLB73150:** The first three notes (G4, A4, B4) are highlighted in green.

# Studying relationships between variants



# Studying relationships between variants

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Het was op een Zondagmorgen / Toen kwam hij mij [...]

Coll Bakker ([1900 ca.]), 057 [nr. 57]

[wijsaanduiding: ontbreekt]

*Daar waren twee koningskinderen (4)*



---

Daar waren twee koningskind'ren / Die hadden [...]

Coll Bakker ([1900 ca.]), 140 [nr. 140]

[wijsaanduiding: ontbreekt]

*Daar waren twee koningskinderen (4)*



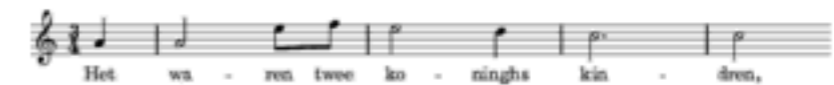
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Het waren twee koninghs kindren, / sy hadden [...]

43. Het waren twee koninghs kindren. B.

Van Duyse (1903-1908), I, p234 [nr. 107]

*Daar waren twee koningskinderen (1)*



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Het waren twee conincskinderen, / sy hadden [...]

43. Het waren twee conincskinderen. C.

Van Duyse (1903-1908), I, p235 [nr. 108]

*Daar waren twee koningskinderen (2)*



# Use of characteristic licks and patterns

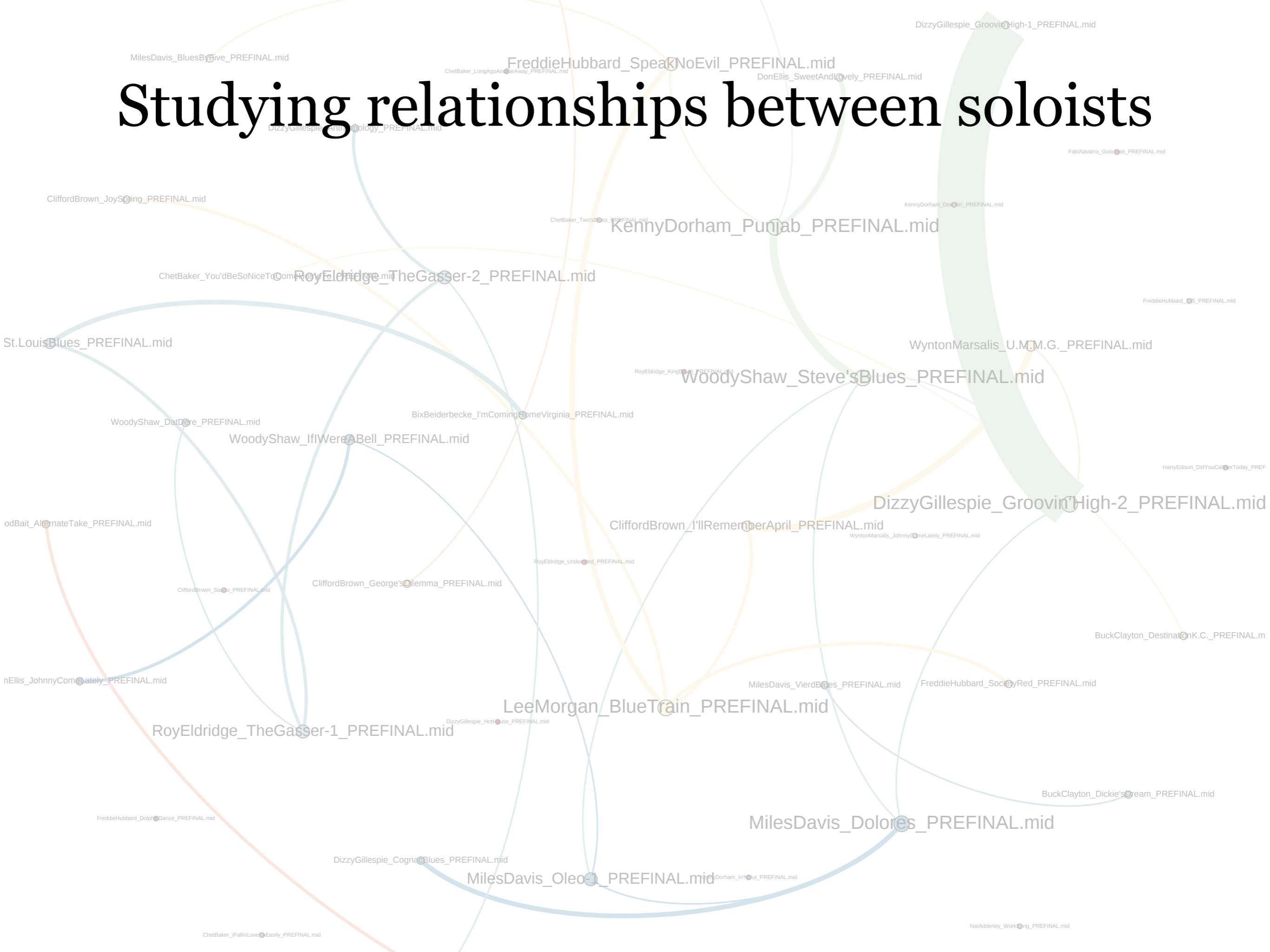
A musical notation snippet in 4/4 time. It starts with a C7 chord and a quarter rest. The melody consists of eighth notes: C4, D4, E4, F4, G4, A4, B4, A4, G4, F4, E4, D4. A triplet of eighth notes (E4, F4, G4) is marked with a '3' below it. The piece concludes with a B7 chord and a quarter rest.

This lick is located in measure number 9 of [Charlie Parker's Ornithology solo](#)

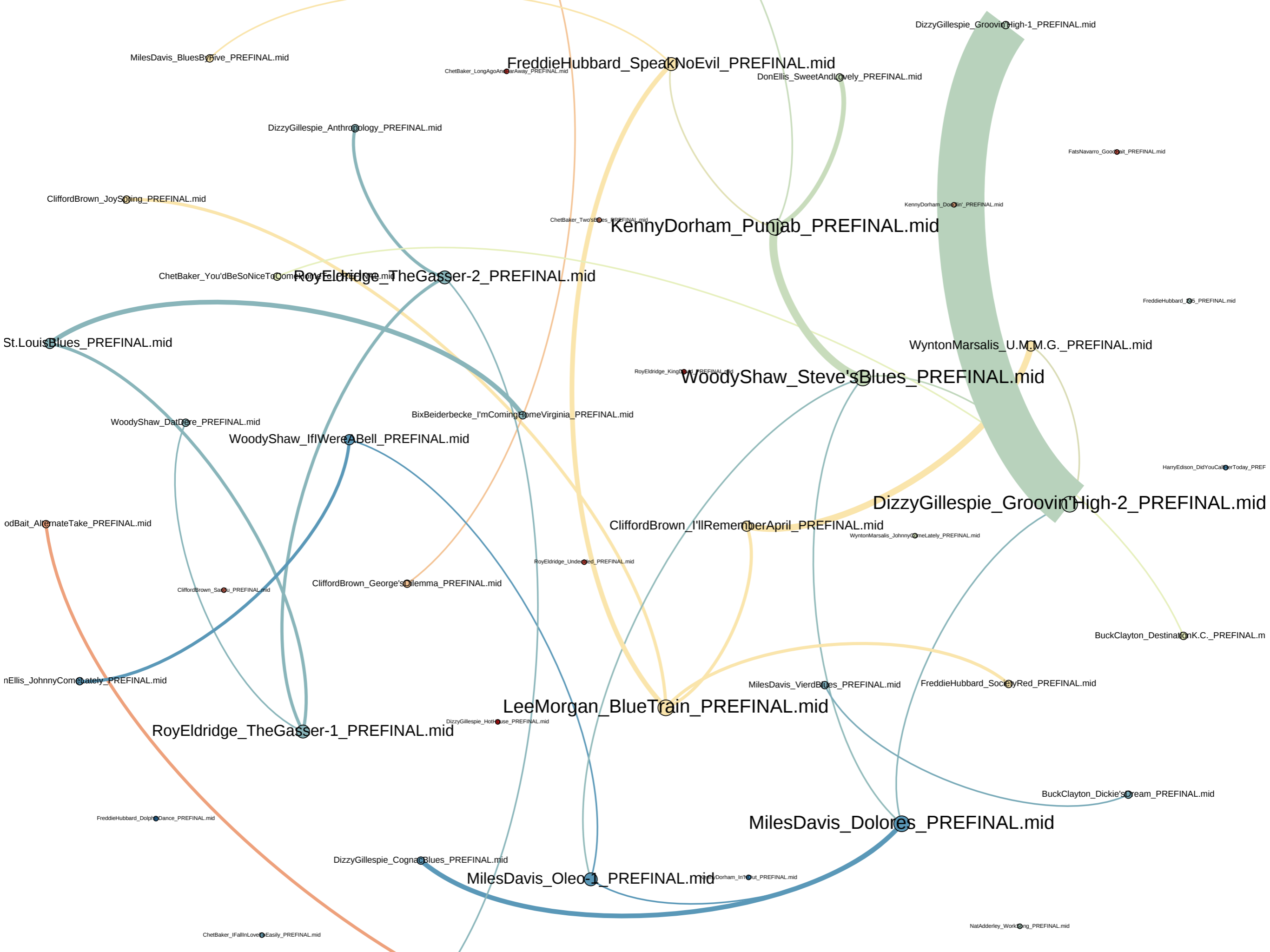


A series of six musical notation examples, each consisting of a single staff with a treble clef and a common time signature. Each example shows a sequence of notes with three chord changes indicated above the staff: D-7, G7, and C#7. The notes are primarily eighth and quarter notes, often beamed together in groups of three or four.

# Studying relationships between soloists







# Outline

- Similarity measures
- Material
- Music representation
- Pattern matching
- Evaluation method
- Comparison of similarity measures
- Influence of pattern length

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# Similarity measures

- alignment measures
- simple measures
- curve measures

# Similarity measures

- events  $i$  in melodies  $x$  and  $y$

# Similarity measures

## Levenshtein distance

$$LD(x_i, y_i) = \min \begin{cases} LD(x_{i-1}, y_i) + 1 \\ LD(x_i, y_{i-1}) + 1 \\ LD(x_{i-1}, y_{i-1}) + 1_{(x_i \neq y_i)} \end{cases}$$

Transposition invariant

Time scale invariant

# Similarity measures

## Substitution distance

$$SD(x_i, y_i) = \min \begin{cases} SD(x_{i-1}, y_i) + 1 \\ SD(x_i, y_{i-1}) + 1 \\ SD(x_{i-1}, y_{i-1}) + |x_i - y_i| \end{cases}$$

- Transposition invariant
- Time scale invariant

# Similarity measures

## kMismatch

$$\text{sim}_{kmm}(x, y) = \sum_{i=1}^{i=n} 1_{(x_i \neq y_i)}$$

- Transposition invariant
- Time scale invariant



# Similarity measures

## Difference

$$sim_{diff}(x, y) = \sum_{i=1}^{i=n} |x_i - y_i|$$

- Transposition invariant
- Time scale invariant

# Similarity measures

## Correlation

$$sim_{corr}(x, y) = \frac{1}{n} \sum_{i=1}^{i=n} \frac{(x_i - \bar{x})(y_i - \bar{y})}{\sigma_x \sigma_y}$$

Transposition invariant

Time scale invariant

# Similarity measures

## Pitch derivative

$$sim_{pd}(x, y) = \int |x'(t) - y'(t)| dt$$

- Transposition invariant
- Time scale invariant

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- **Material**
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# Material

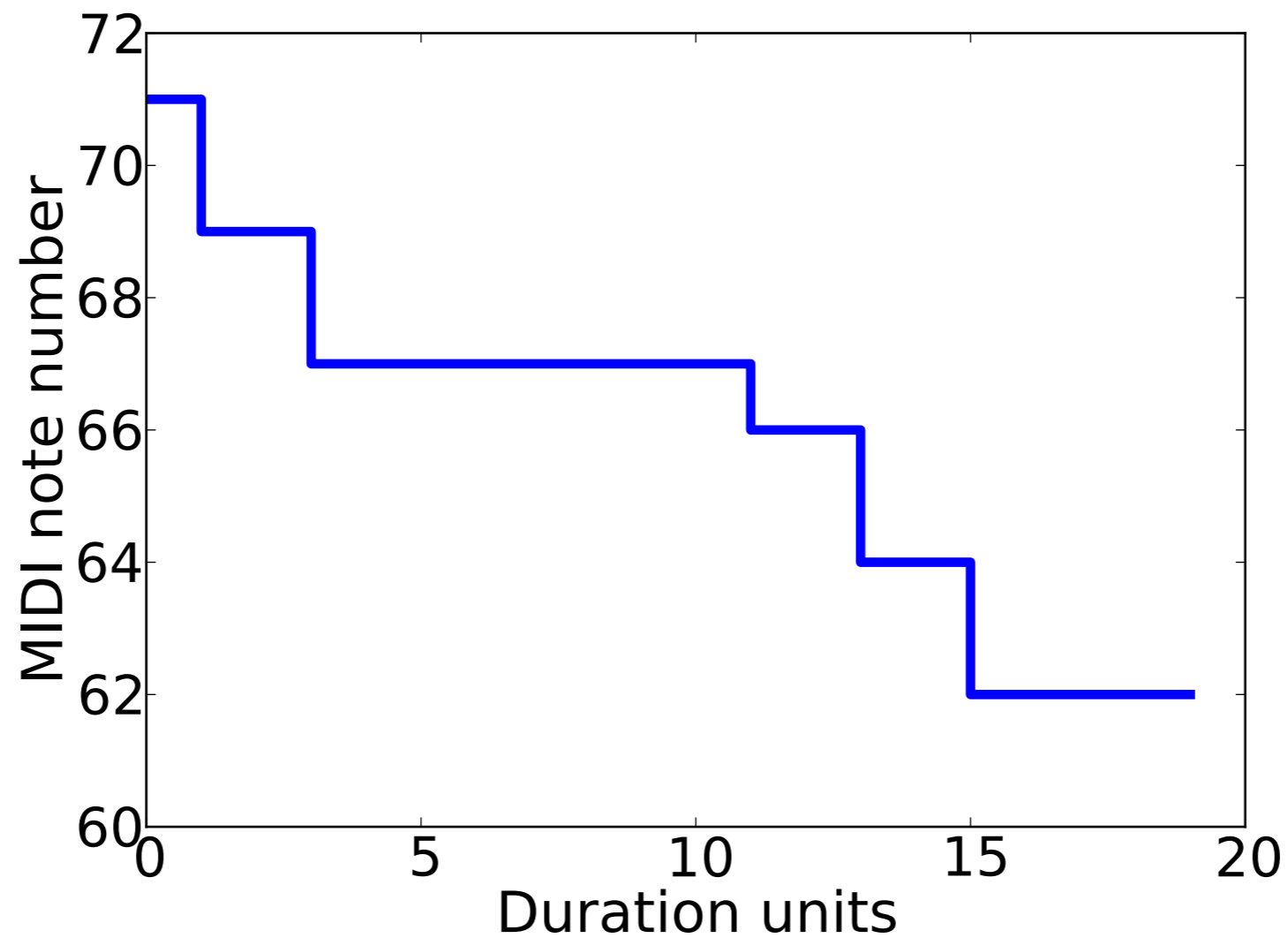
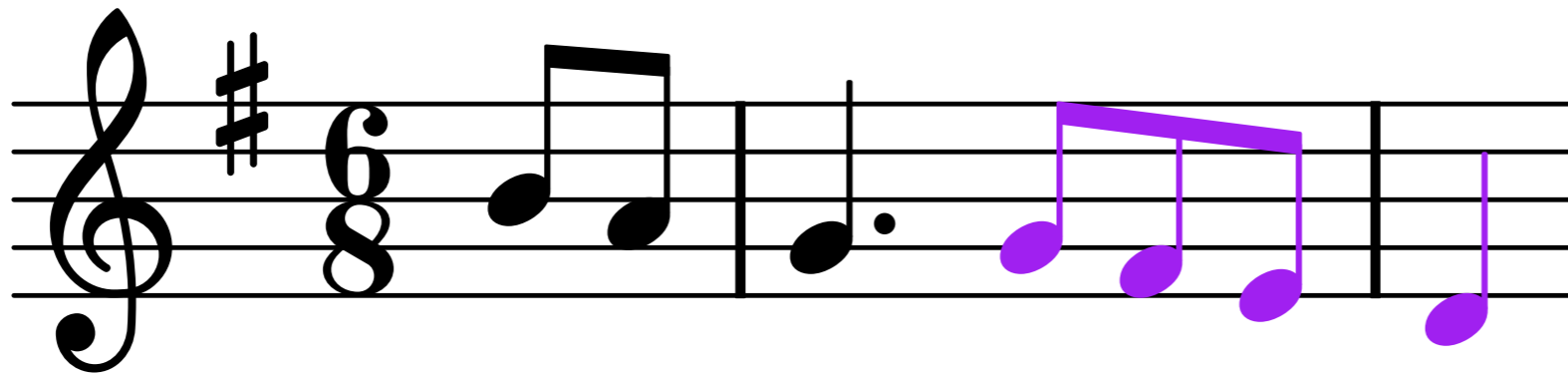
- Dutch folk song database
- [www.liederenbank.nl/mtc](http://www.liederenbank.nl/mtc)
- Annotated corpus: 360 songs
- 1651 annotated motifs, 97 motif classes



# Outline

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# Music representation

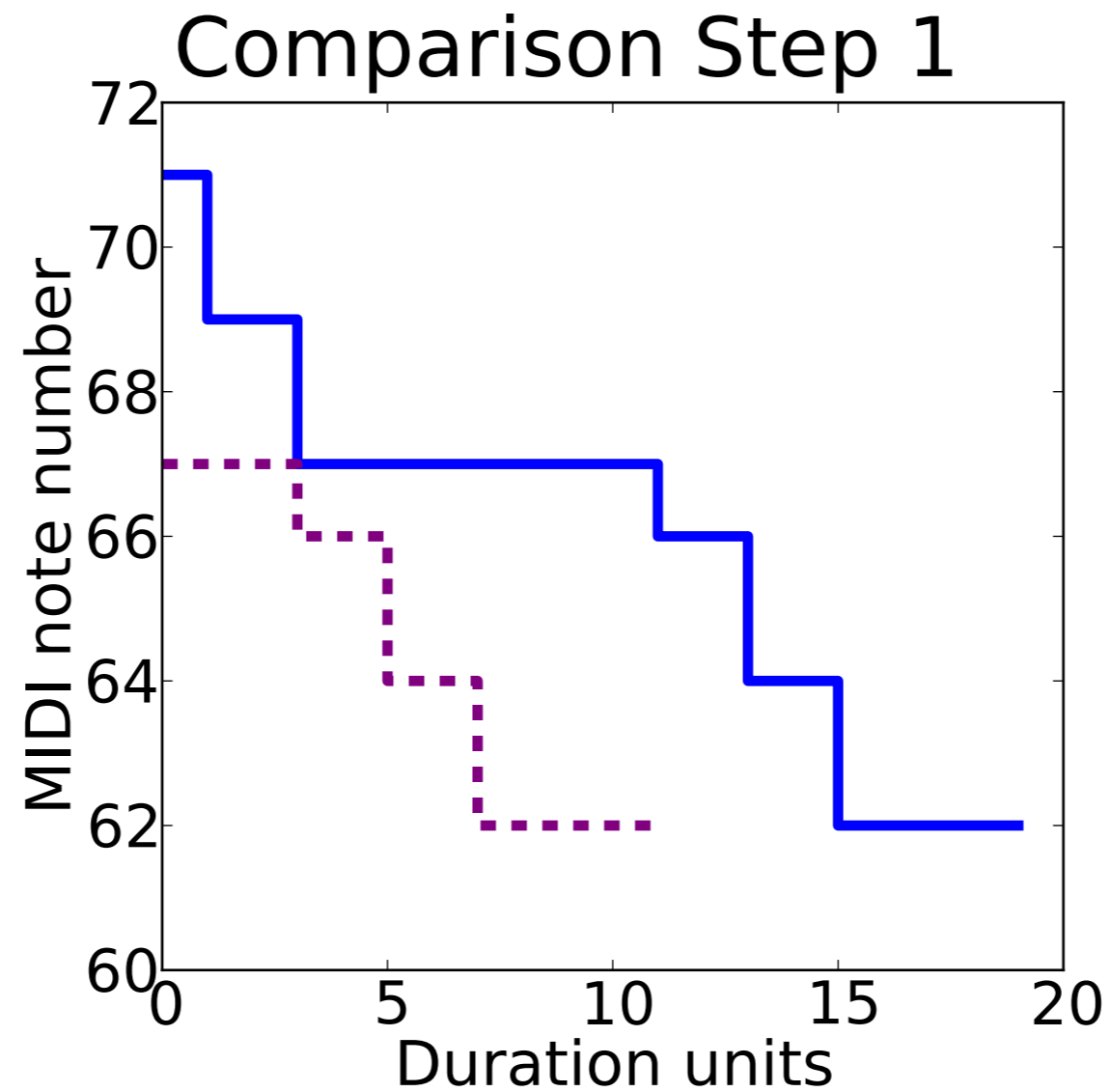




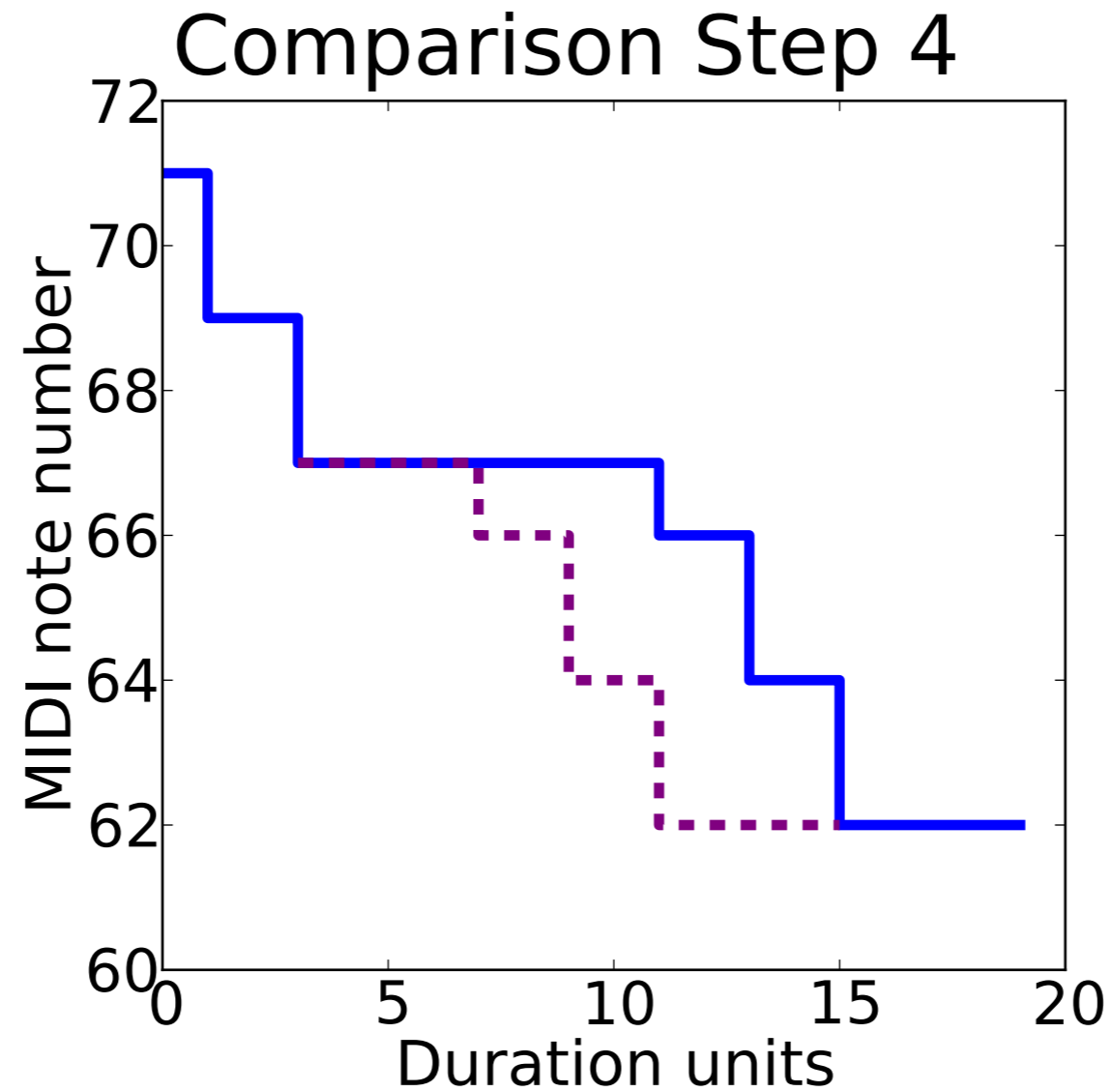
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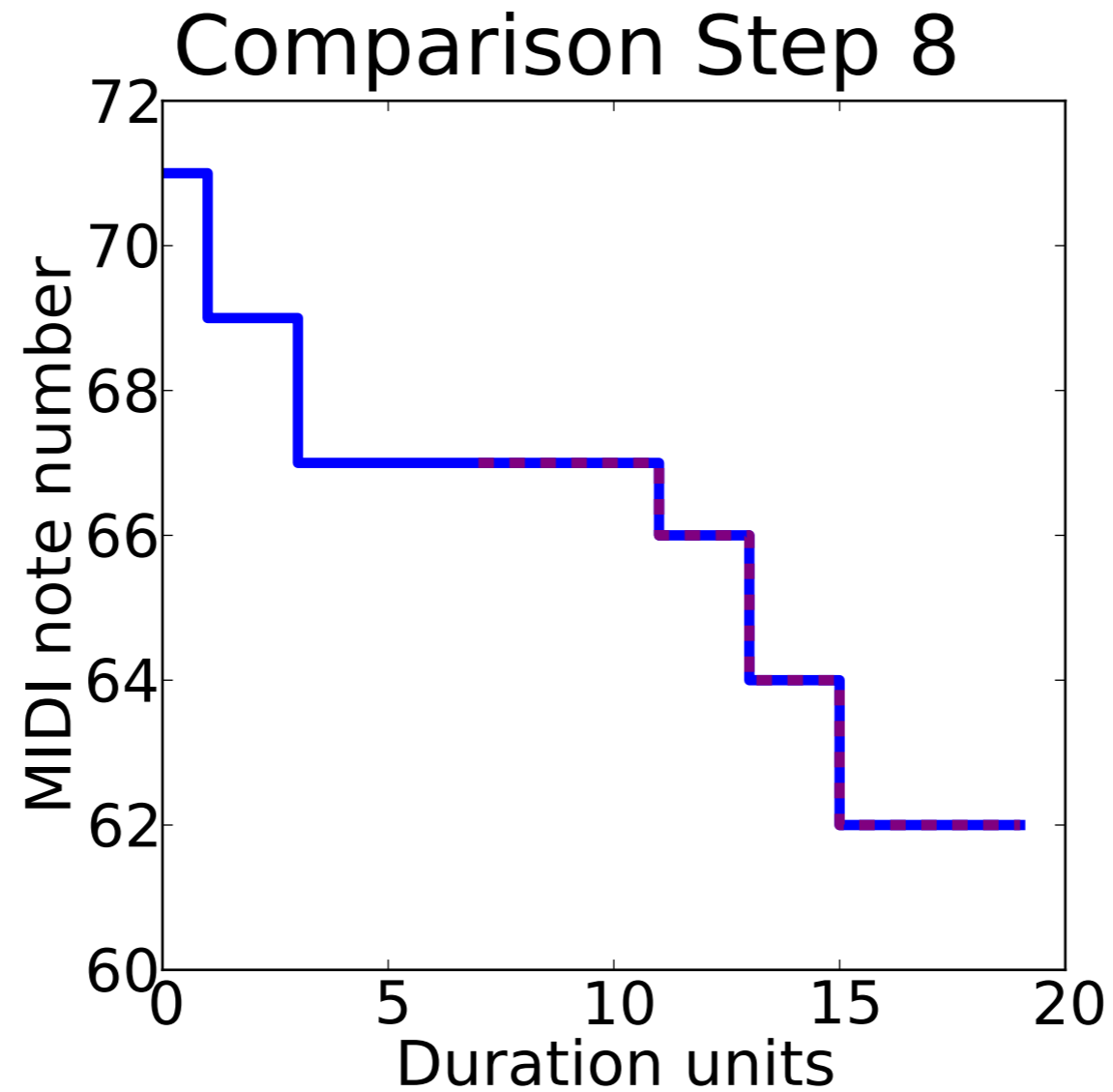
# Pattern matching



# Pattern matching



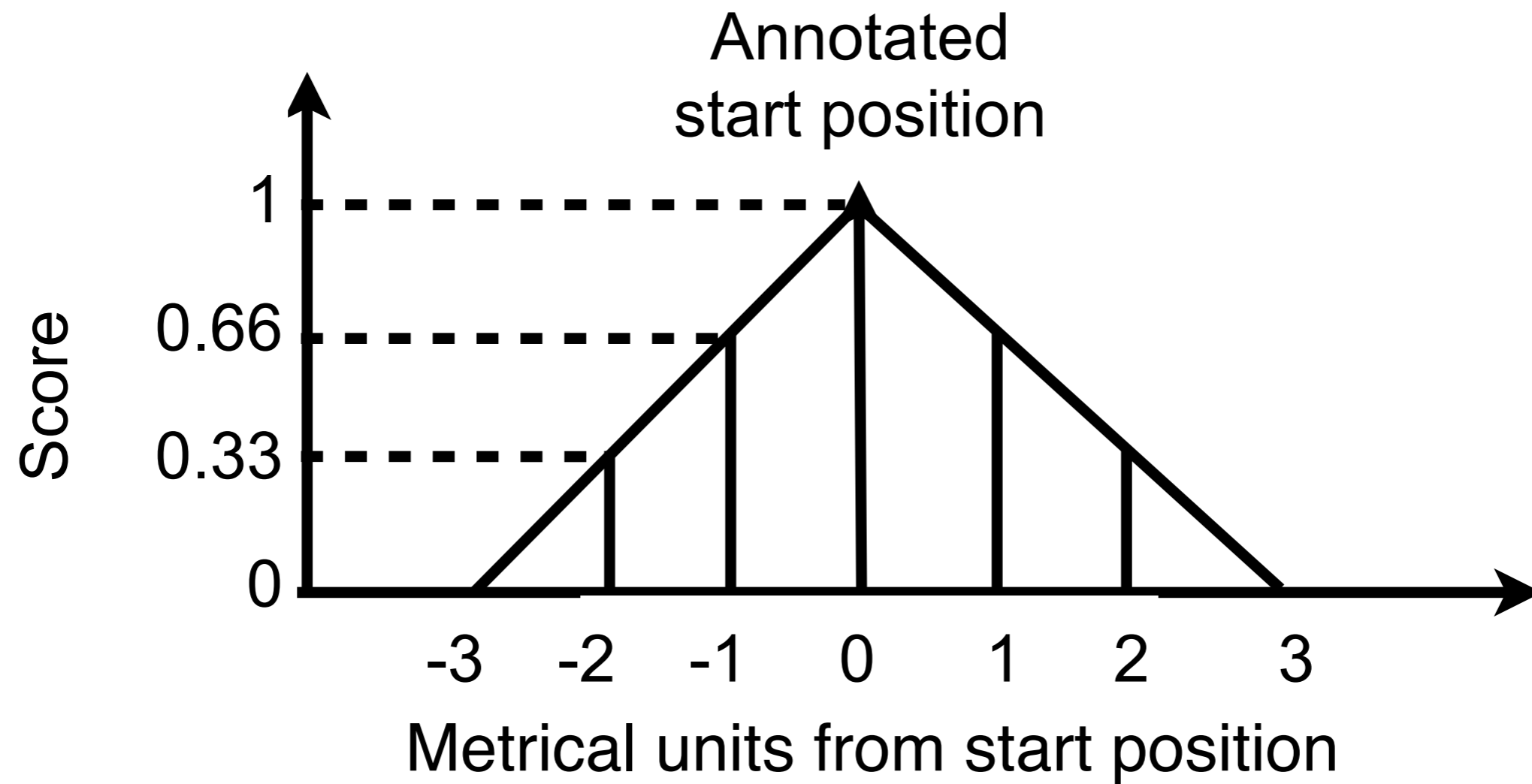
# Pattern matching



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# Evaluation method



# Evaluation method

*true positives (tp):*  
sum of matching scores

*false positives (fp):*  
number of matches, minus tp

*false negatives (fn):*  
squared number of matched motifs  
per motif class, minus tp

# Evaluation method

*Precision:*  $P = \frac{tp}{tp + fp}$

*Recall:*  $R = \frac{tp}{tp + fn}$

*F1, F2, F.5*  $F1 = 2 \cdot \frac{P \cdot R}{P + R}$



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# Comparison of measures

Threshold	Precision	Recall	F.5	F1	F2
0.24	0.634	0.527	0.609	0.575	
0.48	0.393	0.687			0.597

(a) Levenshtein Distance

Threshold	Precision	Recall	F.5	F1	F2
0.24	0.663	0.439	0.602		
0.48	0.582	0.557		0.569	0.562

(b) Substitution Distance

# Comparison of measures

Threshold	Precision	Recall	F.5	F1	F2
0.24	0.633	0.524	0.607		
0.42	0.404	0.668		0.504	0.591

(c) kMismatch

Threshold	Precision	Recall	F.5	F1	F2
0.25	0.656	0.415	0.587		
0.46	0.606	0.484		0.538	
0.95	0.419	0.601			0.553

(d) Difference

# Comparison of measures

Threshold	Precision	Recall	F.5	F1	F2
0.13	0.327	0.395	0.338		
0.24	0.306	0.443		0.362	
0.42	0.215	0.541			0.415

(e) Pitch Derivative

Threshold	Precision	Recall	F.5	F1	F2
0.64	0.140	0.685			0.384
0.991	0.219	0.393		0.282	
0.999	0.222	0.378	0.280		

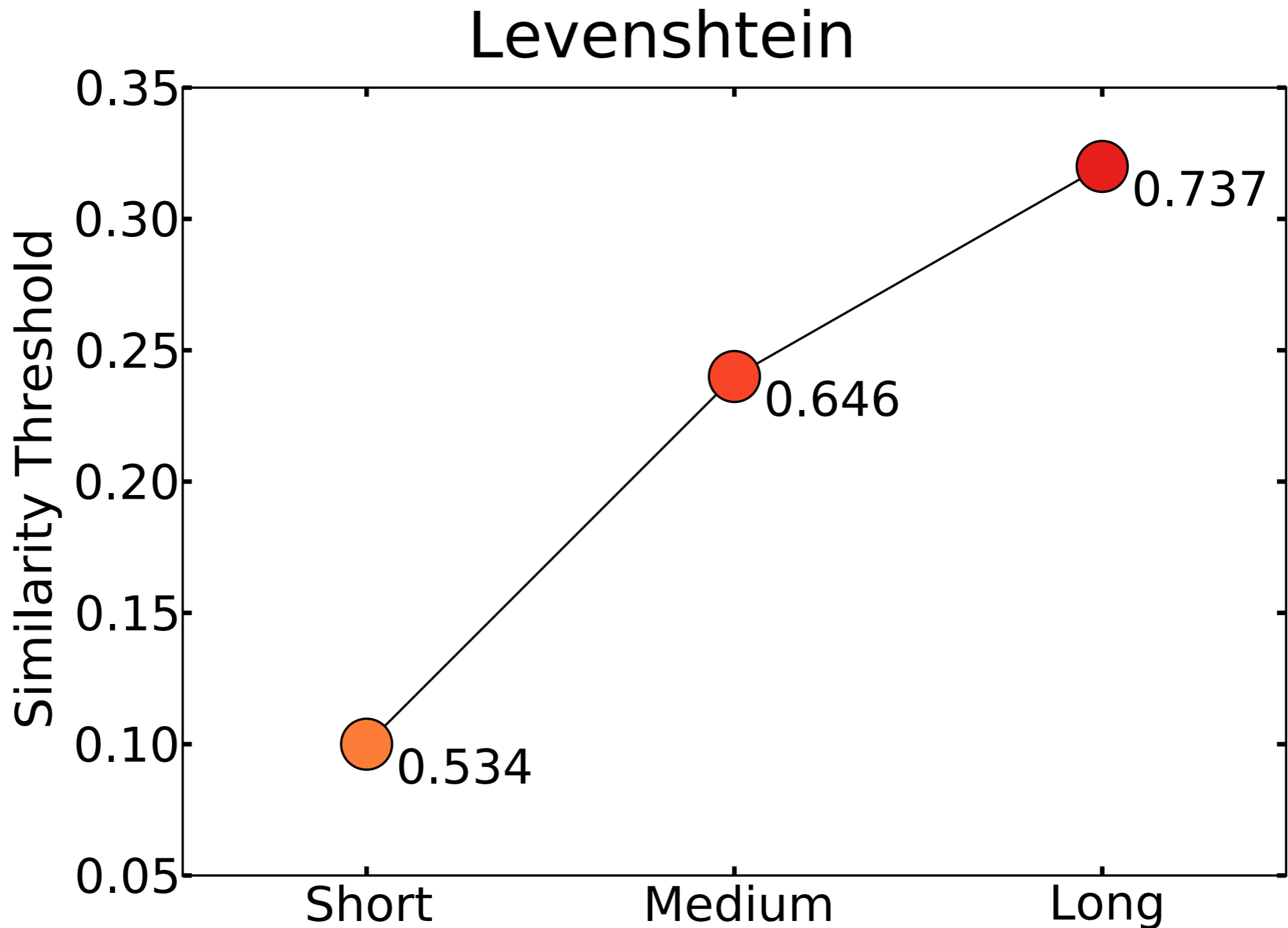
(f) Correlation

# Influence of pattern length

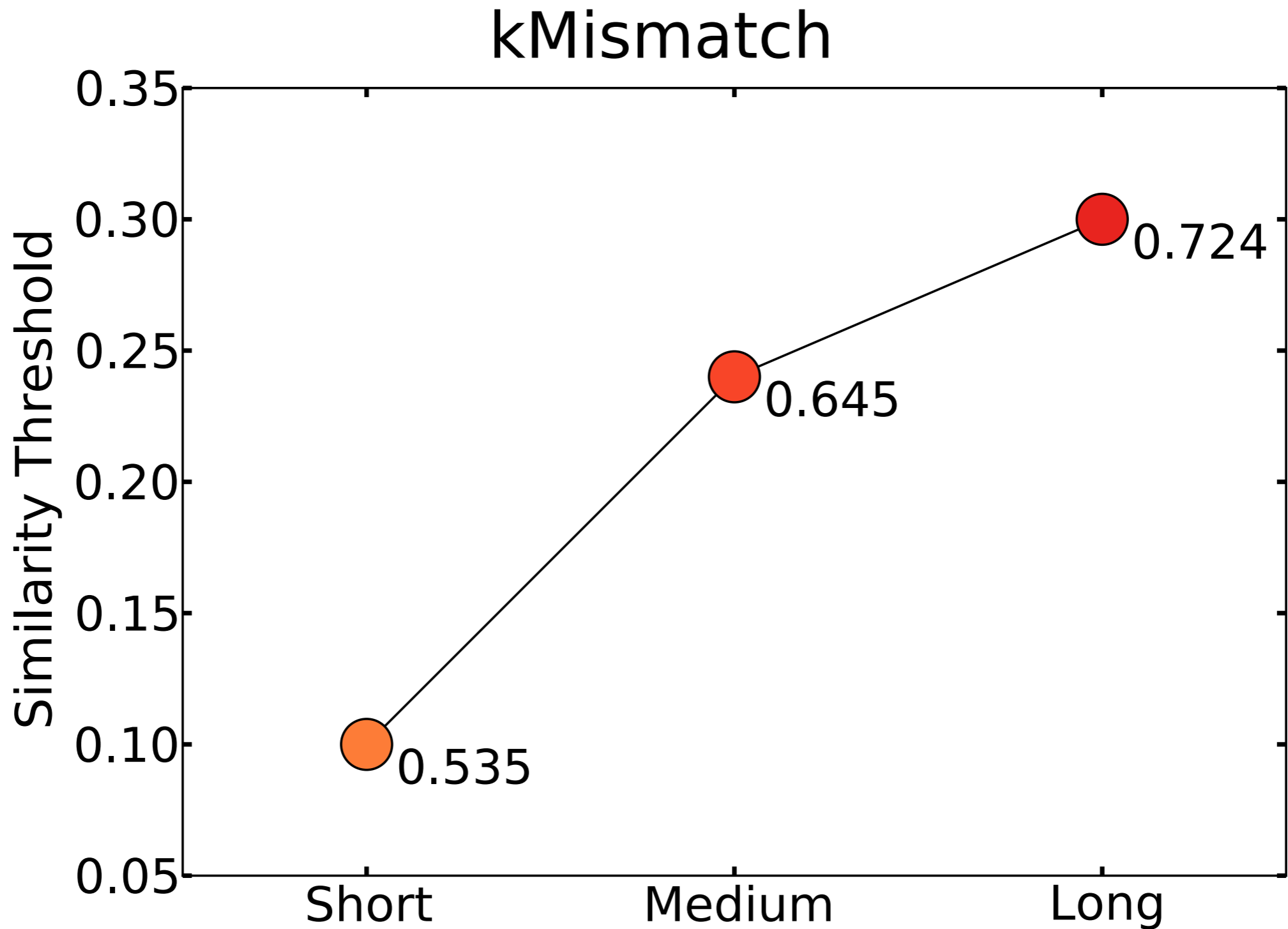
# Influence of pattern length

- short patterns:  $\leq 2$  notes
- medium patterns: 3-5 notes
- long patterns:  $\geq 6$  notes

# Influence of pattern length

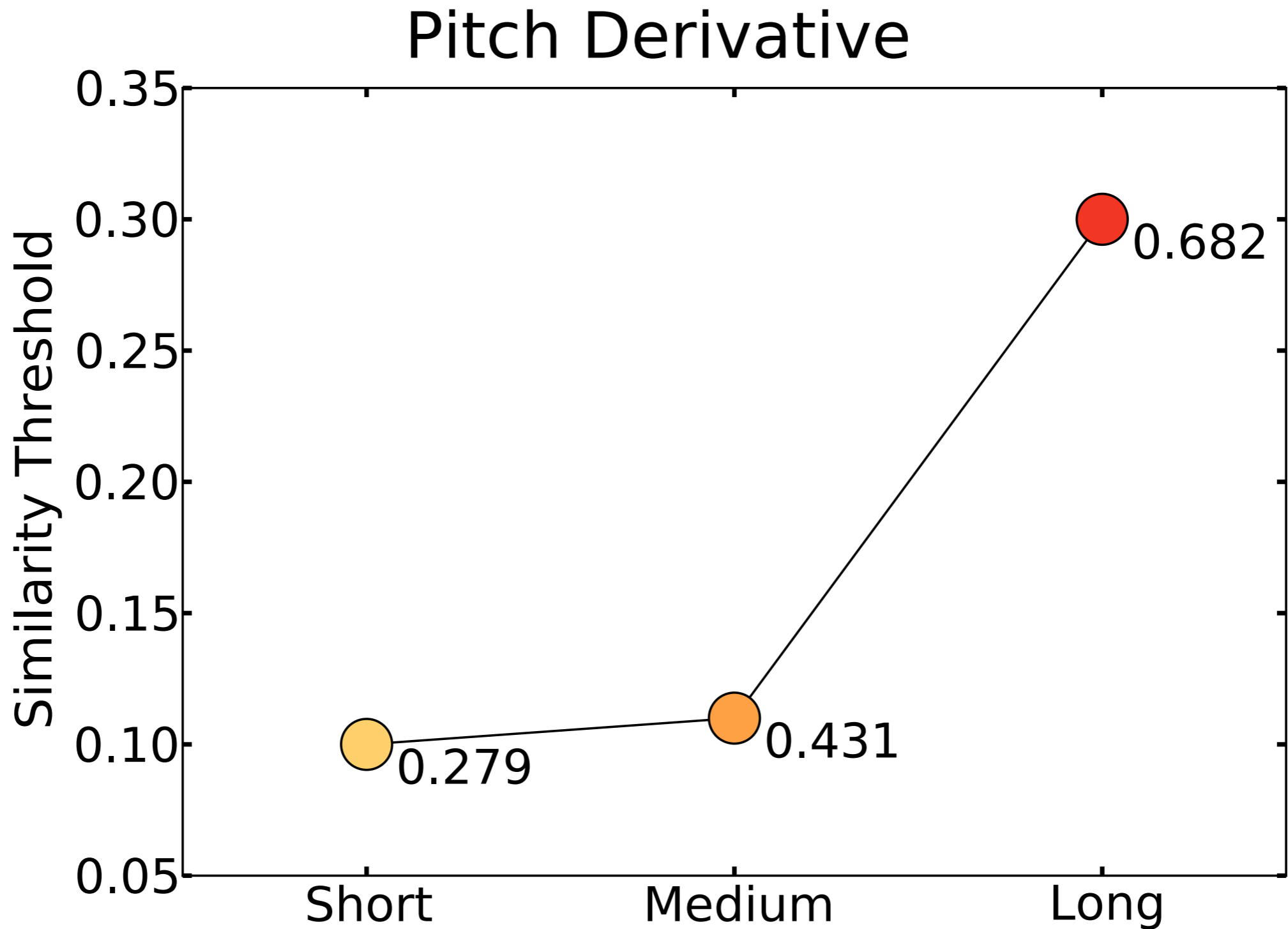


# Influence of pattern length

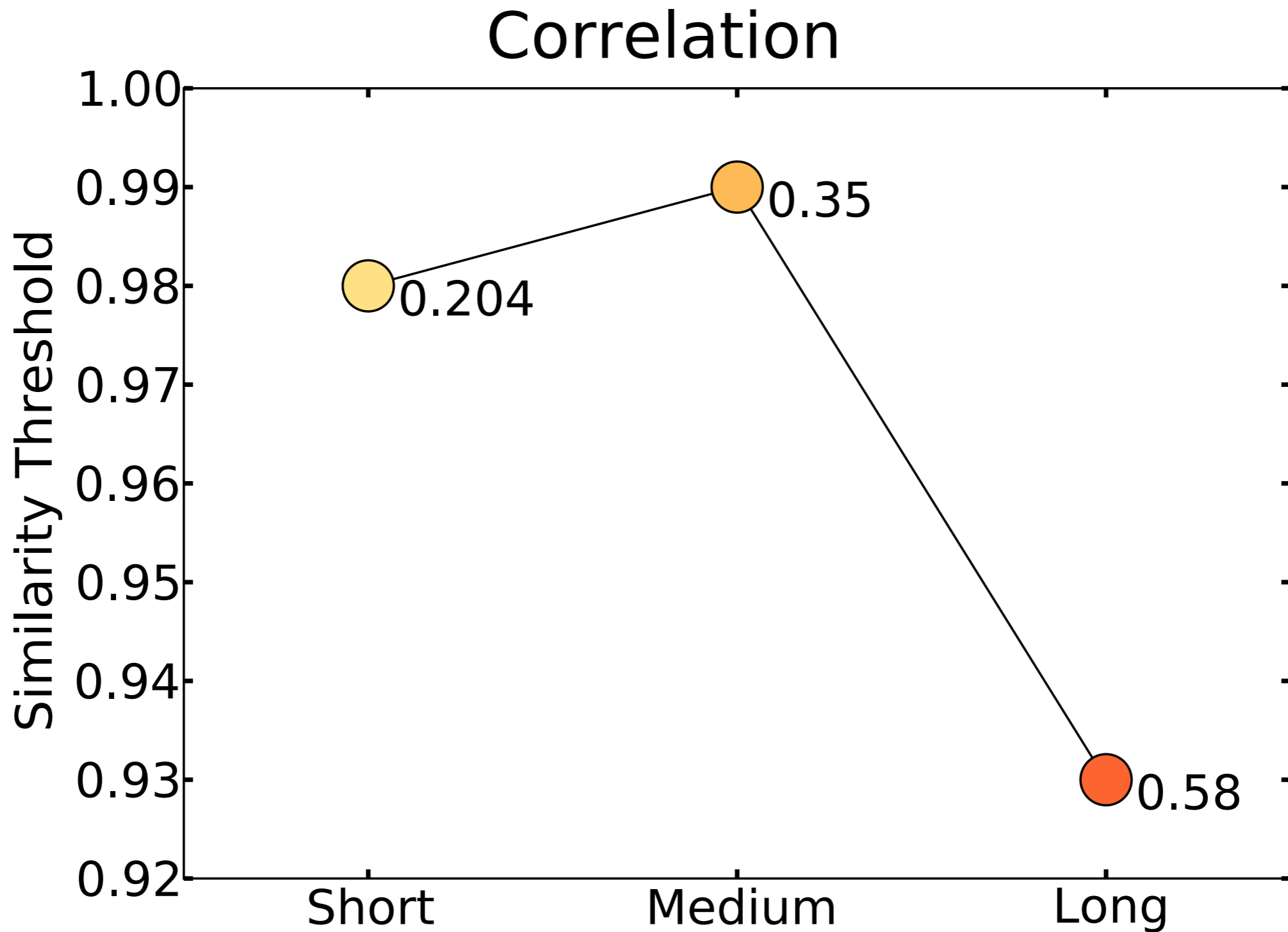




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# Perspectives

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- Influence of music representation



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- Influence of music representation
- Different pattern annotations

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- Influence of music representation
- Different pattern annotations
- Different measures

# Perspectives

- Influence of music representation
- Different pattern annotations
- Different measures
- Efficient implementations

# Thank you!

