

PatternFinder: Symbolic Music Retrieval

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Symbolic Content-Based Music Retrieval

- **Search music by its content:** Given a musical passage, find all of its occurrences (and/or similar occurrences) in a corpus of digitized music scores.
- PatternFinder is software for symbolic music retrieval
- Python package using music21:
<https://github.com/ELVIS-project/patternfinder>
- You can use PatternFinder's web application at
<https://patternfinder.elvisproject.ca>

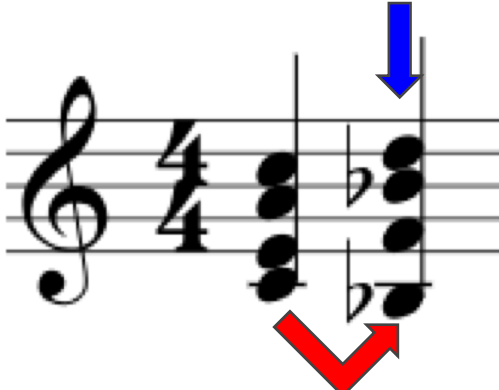
PatternFinder Web Application: <https://patternfinder.elvisproject.ca>

- **Query:** written in the digital music representation “**kern”
- **Search:** An algorithm to find occurrences of our musical passage
- **Filters:** to expand or narrow search results

Entering Your Query

1	**kern	
2	*clefG2	→ Clef
3	*k[]	→ Key Signature
4	*M4/4	→ Time Signature
5	=-	
6	4c e a cc	
7	4B- f b- dd	←

↑



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Algorithm to Find Polyphonic Occurrences

- Developed at the University of Helsinki in 2011
- Searches through polyphonic texture for exact voice leading
- Transpositions
- Partial matching
- Rhythmically altered occurrences

Credo movement of Missa Veni creator spiritus à 6

11

A musical score for six voices in 4/4 time. The score consists of six staves. The first staff (Soprano) has a red half note on G4 in the first measure, which is connected by a diagonal arrow to a red dotted half note on F#4 in the second measure. The second staff (Alto) has a whole rest in the first measure and a red dotted half note on E4 in the second measure. The third staff (Tenor 1) has a whole rest in the first measure and a whole rest in the second measure. The fourth staff (Tenor 2) has a red half note on D3 in the first measure, which is connected by a diagonal arrow to a red dotted half note on D#3 in the second measure. The fifth staff (Bass 1) has a whole rest in the first measure and a red dotted half note on B2 in the second measure. The sixth staff (Bass 2) has a red half note on G2 in the first measure, which is connected by a horizontal arrow to a red dotted half note on F#2 in the second measure.

Query:

A musical query showing two chords. The first chord is a C major triad (C4, E4, G4) in treble clef. The second chord is a C minor triad (C4, E♭4, G4) in bass clef.

PatternFinder Web Application: <https://patternfinder.elvisproject.ca>

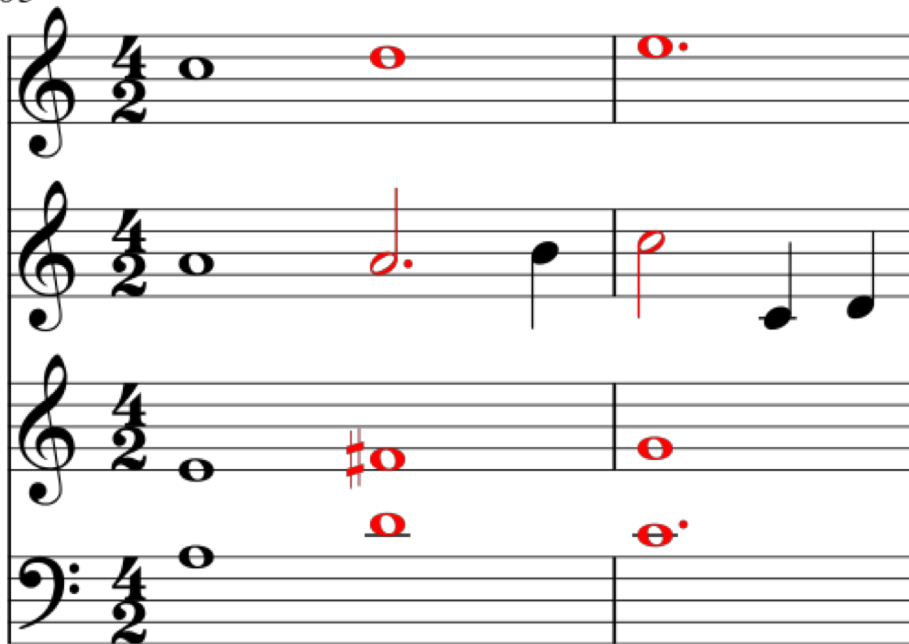
- **Query:** written in the digital music representation “**kern”
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Filters

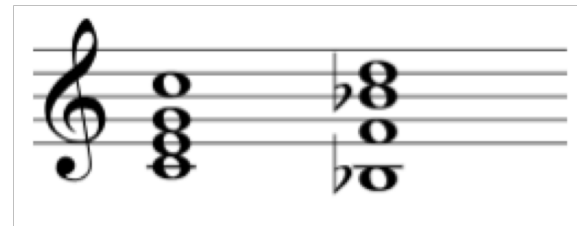
- Partial matches
- Transpositions
- Intervening notes

Gloria movement of In te domine speravi à 4: one intervening note

105

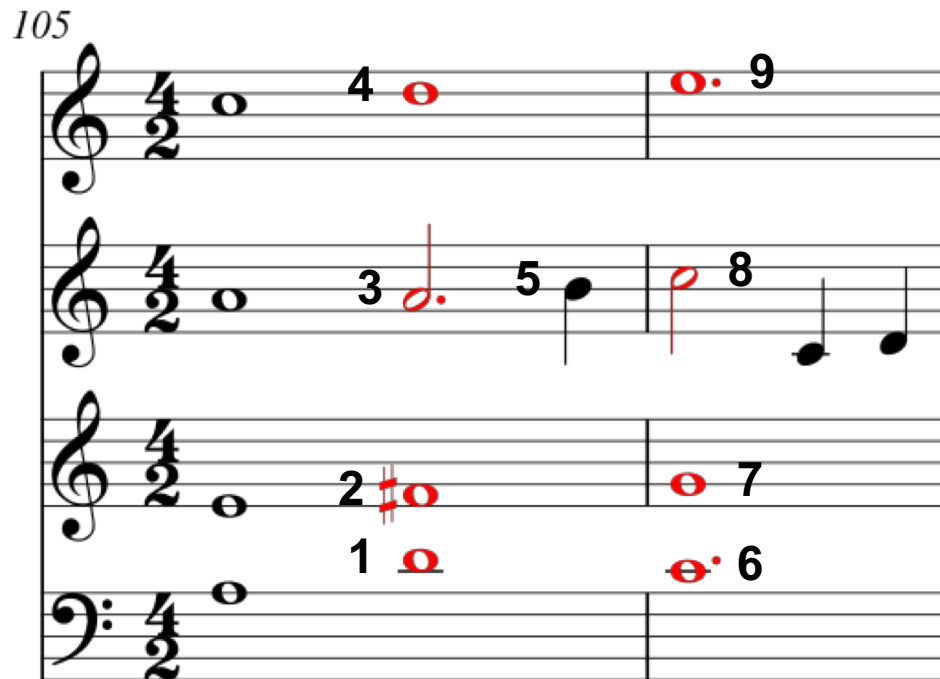


Query:



Gloria movement of In te domine speravi à 4: one intervening note

105



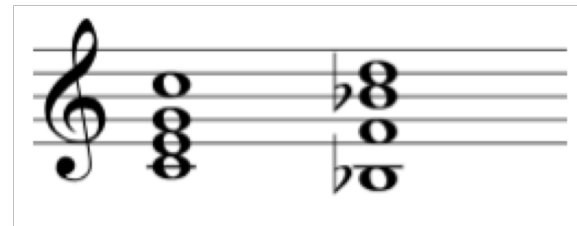
4 9

3 5 8

2 7

1 6

Query:



Credo Movement of Missa Memor esto à 5: three intervening notes

153

The musical score consists of five staves in 4/2 time. The notes are as follows:

- Staff 1: Dotted half, quarter, quarter, quarter, red 4, red 9, red 13, half, half.
- Staff 2: Dotted half, quarter, quarter, quarter, red 3, red 8, quarter, quarter, quarter, quarter, quarter, quarter.
- Staff 3: Dotted half, quarter, quarter, quarter, red 2, quarter, quarter, quarter, quarter, quarter, quarter, quarter, quarter.
- Staff 4: Dotted half, quarter, quarter, quarter, red 1, quarter, quarter, quarter, quarter, quarter, quarter, quarter, quarter.
- Staff 5: Dotted half, quarter, quarter, quarter, red 5, quarter, quarter, quarter, quarter, quarter, quarter, quarter, quarter.

Arrows indicate the sequence of notes: from Staff 1 (red 4) to Staff 2 (red 3), from Staff 2 (red 8) to Staff 3 (red 2), from Staff 3 (red 7) to Staff 4 (red 1), and from Staff 4 (red 6) to Staff 5 (red 5). A horizontal arrow also points from Staff 1 (red 4) to Staff 1 (red 9).

Query:

The query shows two chords in C major: a C major triad (C4, E4, G4) and a Bb major triad (Bb3, D4, F4).

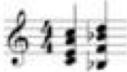
Order: E, C, A, C, B, (intervening D, D), F, Bb, (intervening Bb, D, Bb), D

Demo

Peters/index About Settings

Powered by **Screencastify**

1. **key
2. %def52
3. %12
4. %50-
5. ...
6. ...
7. 40- T 5- 80




Search


Powered by **Vivino Handrum Viewer and Ace text editor**

#23 Occurrences

Tu es Petrus ('1601) Credo à 6



Dies sanctificatus Credo à 4



Filter out interval transpositions?

of intervening notes: 0

Chromatic transpositions mod 12: -12 12

Future Work

- Better indexing methods for faster search
- Experiment with ranking system
- Query interface
- Index data directly from SIMSSA DB

SIMSSA | Single Interface for Music | Score Searching and Analysis



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Credo Movement of Missa Tu es Petrus à 6: four intervening notes

144

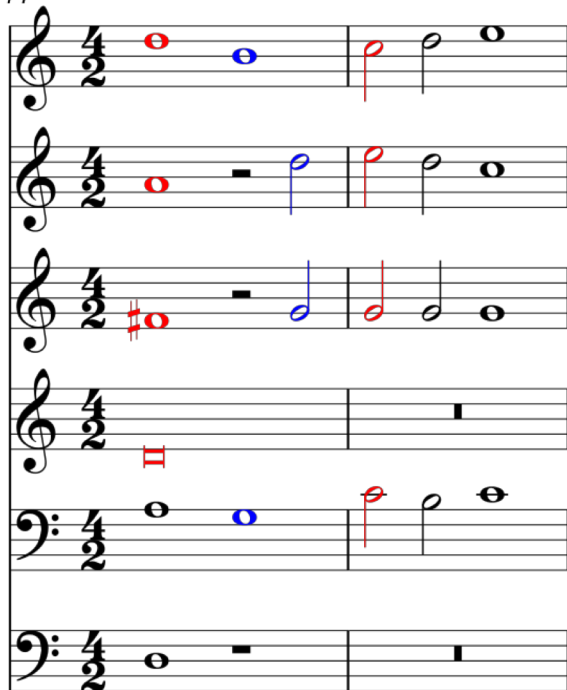
A musical score for six voices in 4/2 time, measures 144-145. The staves are arranged in three pairs. The first pair (Soprano and Alto) has a red half note on G4 in measure 144 and a red half note on A4 in measure 145. The second pair (Tenor 1 and Tenor 2) has a red half note on G4 in measure 144 and a red half note on A4 in measure 145. The third pair (Bass 1 and Bass 2) has a red half note on G3 in measure 144 and a red half note on A3 in measure 145. The notes are marked with red stems and red note heads.

Query:

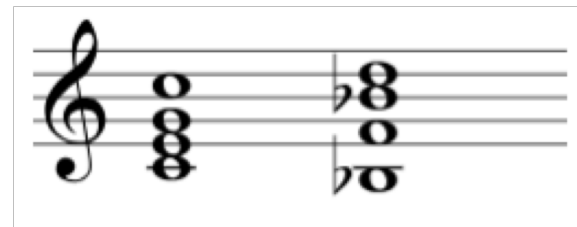
A musical query showing two measures of a six-part setting. The first measure is in treble clef and the second is in bass clef. Both measures show a six-part setting of a single note, with the notes arranged in a hexagonal pattern. The notes are marked with red stems and red note heads.

Credo Movement of Missa Tu es Petrus à 6: four intervening notes

144



Query:



Credo movement of In semiduplicibus majoribus à 5 (only one intervening note, but still noise)

155

A musical score for a Credo movement, measure 155. The score is written for five staves in 4/2 time, with a key signature of one flat (B-flat). The staves are arranged in two pairs (treble and bass) with a fifth staff at the bottom. The notation includes various note values, rests, and accidentals. Red dots and arrows highlight specific notes and intervals, indicating a sequence of notes that are close together, creating a 'noise' effect. The arrows point from a note in the bottom staff to a note in the fourth staff, and from a note in the third staff to a note in the second staff.

Query:

A musical notation query showing two chords. The first chord is a triad in the treble clef, consisting of a quarter note G4, a quarter note A4, and a quarter note B4. The second chord is a triad in the bass clef, consisting of a quarter note G2, a quarter note A2, and a quarter note B2. Both chords are marked with a red 'X'.

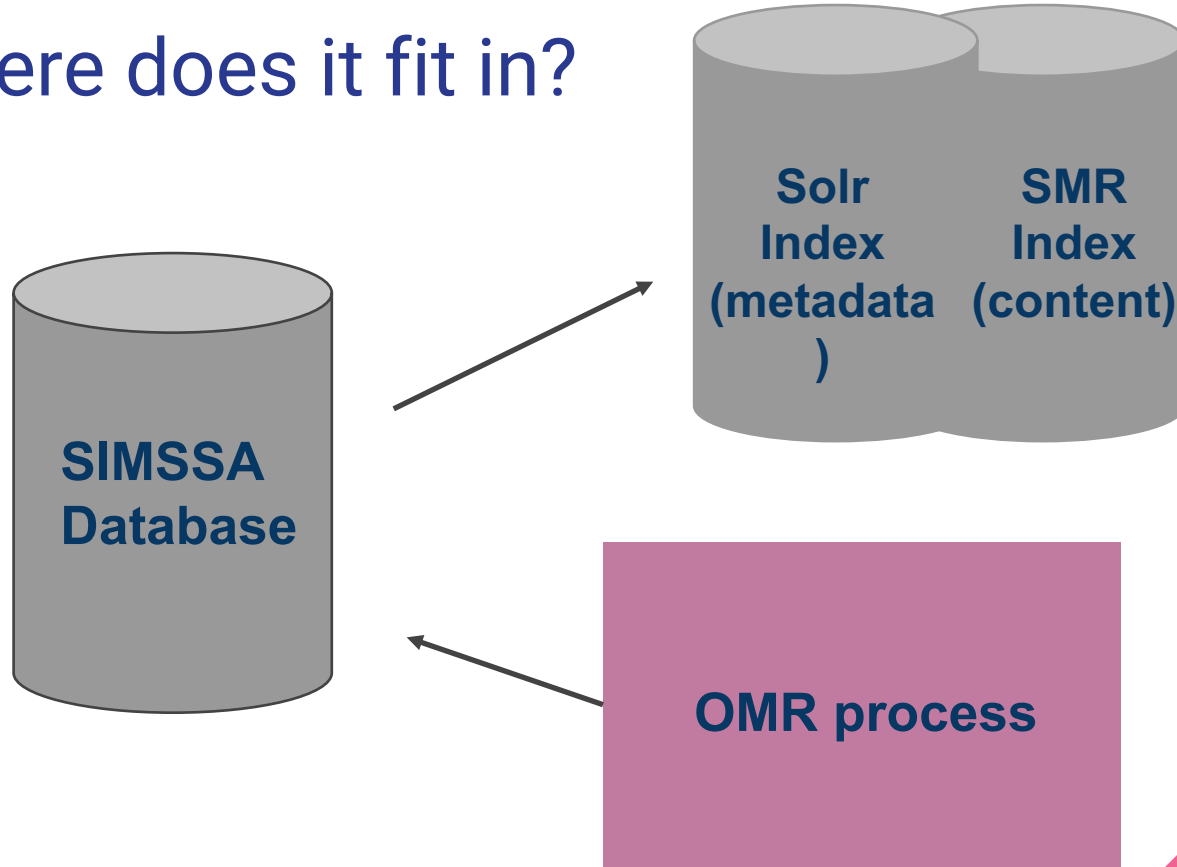
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Filters

- Partial matches
- Transpositions
- Intervening notes

Where does it fit in?



Symbolic music retrieval: desirable traits

- A music query should be found even when embedded in a larger context
 - e.g. solo cello suite melody vs bass
 - e.g. orchestral piano reduction

Symbolic music retrieval: desirable traits

- A music query should be found even when embedded in a larger context
- Notions of similarity: not just verbatim statements of the query, but also “similar” ones

Notions of similarity

- Transpositions
- Rhythmic variations
- Partial matches of a query

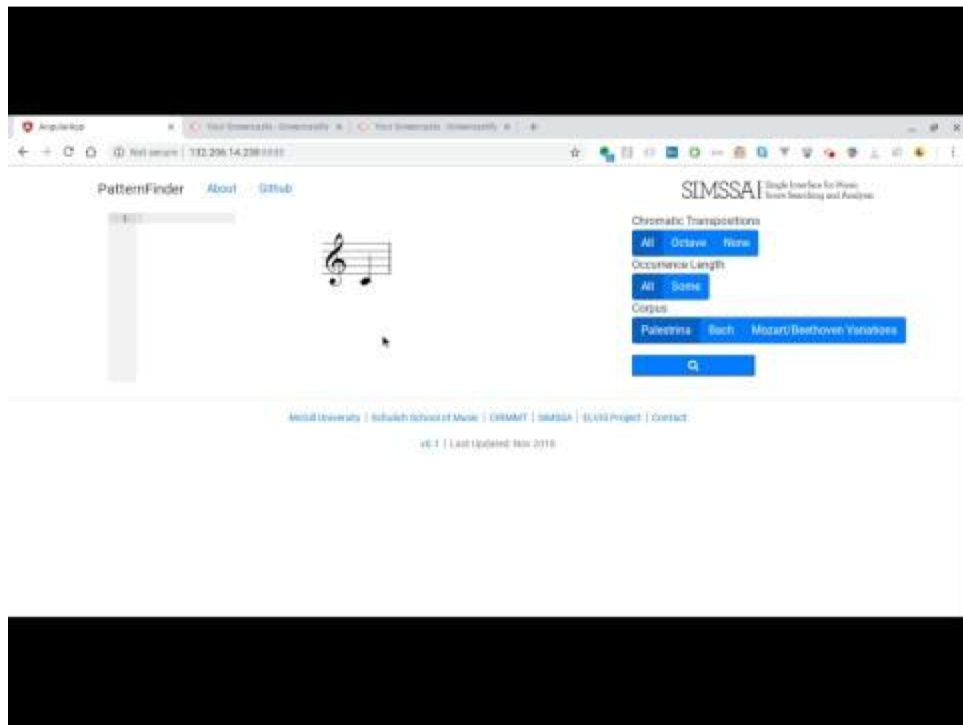
Symbolic music retrieval: desirable traits

- A music query should be found even when embedded in a larger context
- Notions of similarity: not just verbatim statements of the query, but also “similar” ones
- Ranked comparison between occurrences
- Highlighted excerpt of the content

What do we have now?

- Experimental search service at patternfinder.elvisproject.ca
 - Three corpora: Palestrina masses, Bach fugues, Mozart/Beethoven Themes & Variations
- Simple ranked comparison between occurrences
 - Size of partial matching
- Highlighted excerpt of the content
 - Api for serving excerpts
- Similarity:
 - Transpositions, rhythmic variation

Patternfinder demo



Future work

- Better indexing methods for faster search
- Experiment with ranking system
- Query interface
- Index data directly from SIMSSA DB

SIMSSA | Single Interface for Music | Score Searching and Analysis



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Embedded in a larger context

153

The musical score consists of five staves in 4/2 time. The notes and their indices are as follows:

- Staff 1: 4 (red), 9 (red), 13 (red), then a whole note.
- Staff 2: 3 (red), 8 (red), then two eighth notes.
- Staff 3: 2 (red), 7, 12, then a whole note.
- Staff 4: 1 (red), 6, 11, then a whole note.
- Staff 5: 5 (red), 10, then a whole note.

Arrows indicate the sequence of red notes: 4 → 9 → 8 → 2 → 1 → 5.

Query:

The query shows two chords in C major and C minor: C-E-G and C-Bb-G.

Order: E, C, A, C, B, (intervening D, D), F, Bb, (intervening Bb, D, Bb), D

Query A2 in *Spem in alium*

Query A2

Tenor

Bass

Puis - que j'ay per - du mon a

per - - - du

Detailed description: This block shows the musical notation for the Tenor and Bass parts of 'Query A2'. The Tenor part is written on a single staff with a treble clef and a key signature of one flat (B-flat). It begins with a whole rest, followed by a half note G4, a half note A4, a half note B4, a whole note C5, a half note D5, and a whole note E5. The Bass part is written on a single staff with a bass clef and a key signature of one flat. It begins with a whole rest, followed by a half note G3, a half note A3, a half note B3, a half note C4, a half note D4, a half note E4, a whole note F4, and a whole note G4. The lyrics 'Puis - que j'ay per - du mon a' are aligned under the Tenor part, and 'per - - - du' are aligned under the Bass part.

Soprano

Alto

Tenor

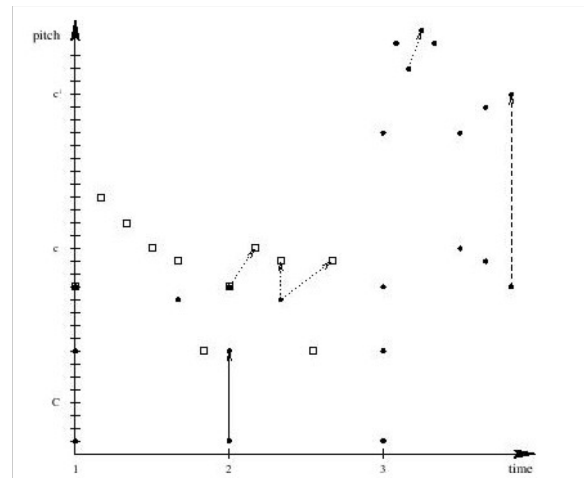
Bass

Detailed description: This block shows the musical notation for the Soprano, Alto, Tenor, and Bass parts of 'Query A2'. The Soprano part is written on a single staff with a treble clef and a key signature of one flat. It begins with a half note G4, a half note A4, a half note B4, a whole note C5, a half note D5, a half note E5, and a whole note F5. The Alto part is written on a single staff with a treble clef and a key signature of one flat. It begins with a half note G4, a half note A4, a half note B4, a whole note C5, a half note D5, a half note E5, and a whole note F5. The Tenor part is written on a single staff with a bass clef and a key signature of one flat. It begins with a half note G3, a half note A3, a half note B3, a half note C4, a half note D4, a half note E4, a whole note F4, and a whole note G4. The Bass part is written on a single staff with a bass clef and a key signature of one flat. It begins with a whole rest, followed by a half note G3, a half note A3, a half note B3, a whole note C4, a half note D4, a half note E4, and a whole note F4. Green arrows indicate the pitch contour for each part, showing the intervals between notes. The Soprano part has a green arrow pointing up from G4 to A4, a green arrow pointing up from A4 to B4, a green arrow pointing up from B4 to C5, a green arrow pointing up from C5 to D5, a green arrow pointing up from D5 to E5, and a green arrow pointing up from E5 to F5. The Alto part has a green arrow pointing up from G4 to A4, a green arrow pointing up from A4 to B4, a green arrow pointing up from B4 to C5, a green arrow pointing up from C5 to D5, a green arrow pointing up from D5 to E5, and a green arrow pointing up from E5 to F5. The Tenor part has a green arrow pointing up from G3 to A3, a green arrow pointing up from A3 to B3, a green arrow pointing up from B3 to C4, a green arrow pointing up from C4 to D4, a green arrow pointing up from D4 to E4, a green arrow pointing up from E4 to F4, and a green arrow pointing up from F4 to G4. The Bass part has a green arrow pointing up from G3 to A3, a green arrow pointing up from A3 to B3, a green arrow pointing up from B3 to C4, a green arrow pointing up from C4 to D4, a green arrow pointing up from D4 to E4, and a green arrow pointing up from E4 to F4.

Point-set Representation



Excerpt from Schubert's *Der Leiermann*

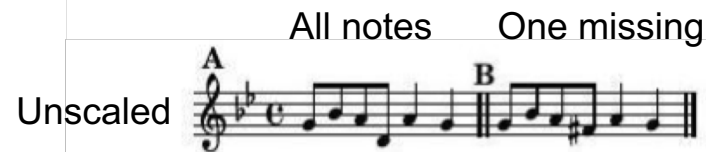


K. Lemström and M. Laitinen. *Transposition and time-warp invariant geometric music retrieval algorithms*. In Proc. ADMIRE'11, Third International Workshop on Advances in Music Information Research, Barcelona, 201

Unscaled similarity: queries A and B



Excerpt from Schubert's *Der Leiermann*

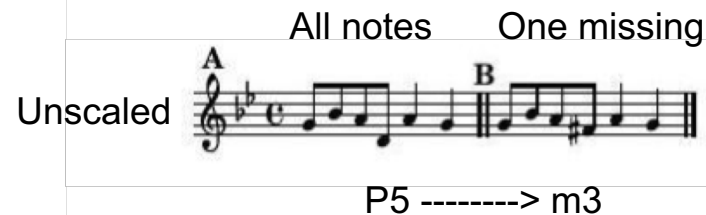


- Transposition invariance : the results of our query should not change based on the key of our query

Unscaled similarity: queries A and B



Excerpt from Schubert's *Der Leiermann*



- Transposition invariance : the results of our query should not change based on the key of our query

Scaled similarity: queries C and D



Excerpt from Schubert's *Der Leiermann*

Unscaled

All notes One missing

Scaled

C D

The image shows two musical queries, C and D, in 2/4 time. Query C is labeled "Unscaled" and "All notes", and query D is labeled "Unscaled" and "One missing". Both queries are shown in a single staff. Query C is a melody starting on G4 and ending on D5. Query D is a melody starting on G4 and ending on D5, but with the second note (A4) missing. The queries are shown in a single staff, with the label "Unscaled" to the left and "Scaled" to the right. The queries are labeled C and D.

- Transposition invariance : the results of our query should not change based on the key of our query
- Time-scaling invariance: augmentation and diminution

Warped similarity: queries E and F



dreht, und seine Leier steht ihm nimmer still,

The image shows a musical score excerpt from Schubert's *Der Leiermann*. It consists of three staves: a vocal line in treble clef, a piano accompaniment in treble clef, and a piano accompaniment in bass clef. The key signature has one flat (B-flat) and the time signature is 3/4. The lyrics are "dreht, und seine Leier steht ihm nimmer still,". Five purple arrows point to specific notes in the vocal line: the first arrow points to the first note (G4), the second to the second note (A4), the third to the third note (Bb4), the fourth to the fourth note (A4), and the fifth to the fifth note (G4). A sixth purple arrow points to the eighth note (F4) in the vocal line.

Excerpt from Schubert's *Der Leiermann*



The image shows a comparison of musical queries E and F. The top section is labeled "Unscaled" and contains two queries: "All notes" (A) and "One missing" (B). The bottom section is labeled "Scaled" and contains two queries: "C" and "D". The bottom section is also labeled "Warped" and contains two queries: "E" and "F". The queries are represented by musical staves with notes and accidentals. The "Unscaled" section shows queries A and B, which are in the key of B-flat major. The "Scaled" section shows queries C and D, which are in the key of B major. The "Warped" section shows queries E and F, which are in the key of B-flat major. The queries E and F are shown with a key signature change from B-flat major to B major, indicating a transposition.

- Transposition invariance : the results of our query should not change based on the key of our query
- Time-scaling invariance: augmentation and diminution
- Time-warping invariance: arbitrary rhythmic warping of individual notes

Warped similarity: queries E and F



The image shows a musical score excerpt from Schubert's *Der Leiermann*. It consists of three staves: a vocal line in treble clef, a piano accompaniment in treble clef, and a piano accompaniment in bass clef. The vocal line has the lyrics "dreht, und seine Leier steht ihm nimmer still,". Five purple arrows point to specific notes in the vocal line: the first arrow points to the first 'e' in "dreht", the second to the first 'e' in "steht", the third to the first 'i' in "ihm", the fourth to the first 'n' in "nimmer", and the fifth to the first 's' in "still".

Excerpt from Schubert's *Der Leiermann*



The image shows a comparison of musical queries A, B, C, D, E, and F. The queries are arranged in a grid with three rows: "Unscaled", "Scaled", and "Warped". The columns are labeled "All notes" and "One missing". The queries are represented by musical staves. Query A is in treble clef, key of B-flat major, 4/4 time. Query B is in treble clef, key of B-flat major, 4/4 time. Query C is in treble clef, key of B-flat major, 4/4 time. Query D is in treble clef, key of B-flat major, 4/4 time. Query E is in treble clef, key of B-flat major, 4/4 time. Query F is in treble clef, key of B-flat major, 4/4 time.

- Transposition invariance : the results of our query should not change based on the key of our query
- Time-scaling invariance: augmentation and diminution
- Time-warping invariance: arbitrary rhythmic warping of individual notes

Piano-roll Representation

Swepline the Music! 331



Figure 1. A melody represented in common music notation.



Figure 2. An excerpt of Einojuhani Rautavaara's opera *Thomas* (1985). Printed with the permission of the publisher Warner/Chappell Music Finland Oy.

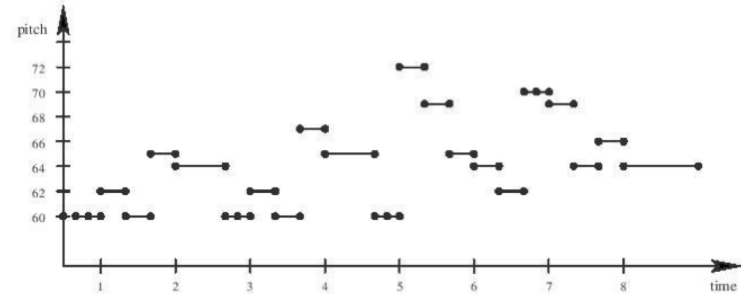


Figure 3. The example of Fig. 1 in piano-roll representation.

Ukkonen, E., Lemström, K., & Makinen, V. (2003). *Swepline the Music! Lecture Notes in Computer Science*, 2598, 330-342.

Threshold



Excerpt from Schubert's *Der Leiermann*



Queries B, D, and F require a threshold of at least 5 (or 85%)
Queries A, C, and E require a threshold of at least 6 (or 100%)

Scale

- Time-scaling liberties taken by the algorithm to find a match
- *Pure*: rhythmically identical occurrences
- *Scaled*: finds augmentation and diminution
- *Warped*: rhythmic values are ignored

Scale



The image shows a musical score excerpt from Schubert's *Der Leiermann*. It consists of three staves. The top staff is in treble clef with a 3/4 time signature. The middle staff is in treble clef with a 4/4 time signature. The bottom staff is in bass clef with a 3/4 time signature. The lyrics "dreht, und seine Leier steht ihm nimmer stil," are written below the top staff. Five purple arrows point down to the notes in the top staff, and one purple arrow points down to the notes in the middle staff.

Excerpt from Schubert's *Der Leiermann*

Queries A and B require a scale of 1
Queries C and D require a scale of 3/2
Queries E and F require 'warped'



The image shows a musical score excerpt from Schubert's *Der Leiermann*. It consists of six staves, each labeled with a letter from A to F. The top staff is in treble clef with a 3/4 time signature. The middle staff is in treble clef with a 4/4 time signature. The bottom staff is in bass clef with a 3/4 time signature. The lyrics "dreht, und seine Leier steht ihm nimmer stil," are written below the top staff. Five purple arrows point down to the notes in the middle staff, and one purple arrow points down to the notes in the bottom staff.

Window

- Number of intervening notes allowed between two matched notes
- Pattern window
- Source window

Window



A musical score snippet in 3/4 time. The top staff contains the melody with the lyrics "dreht, und seine Leier steht ihm nimmer stil,". Five purple arrows point downwards to the notes G4, A4, B4, C5, and B4. A sixth purple arrow points to the final note G4. The bottom two staves show accompaniment.



A musical score snippet in 3/4 time, divided into six measures labeled A through F. Six purple arrows point downwards to the notes G4, A4, B4, C5, B4, and A4 in measures A through F. The bottom two staves show accompaniment.

All queries would require a source window of 4
Queries B, D, F need a pattern window of at least 2