

PatternFinder: Symbolic Music Retrieval

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SIMSSA Workshop XVII: Infrastructure for music discovery
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Symbolic Content-Based Music Retrieval

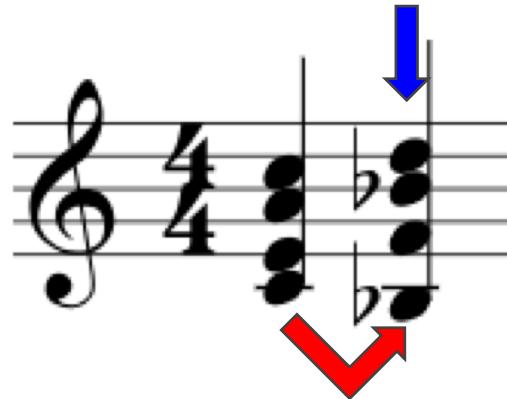
- **Search music by its content:** Given a musical passage, find all of its occurrences (and/or similar occurrences) in a corpus of digitized music scores.
- PatternFinder is software for symbolic music retrieval
- Python package using music21:
<https://github.com/ELVIS-project/patternfinder>
- You can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

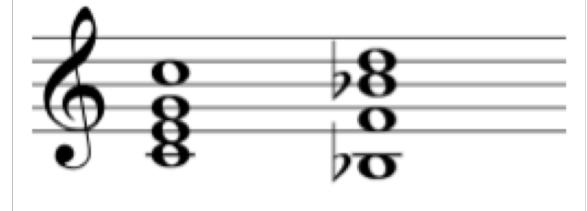
Credo movement of Missa Veni creator spiritus à 6

II

11

4 4 4 2 4 2

Query:



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Filters

- Partial matches
- Transpositions
- Intervening notes

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

105

The musical score consists of four staves, each with a treble clef and a '2' below it, indicating 2/4 time. The first staff starts with a whole note followed by a half note. The second staff starts with a whole note followed by a dotted half note. The third staff starts with a whole note followed by a half note with a sharp sign above it. The fourth staff starts with a whole note followed by a half note with a sharp sign above it. A vertical bar line separates the first three staves from the fourth. Red markings are present: a red dot above the first half note in the first staff, a red dot above the first half note in the second staff, a red dot above the first half note in the third staff, and a red dot above the first half note in the fourth staff.

Query:

A single staff in G major (indicated by a treble clef) and 8/8 time. It features a bass note on the first beat, followed by a bass note on the second beat. The bass note on the second beat has a sharp sign above it, indicating a临时升调 (temporary raise).

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

105

The musical score consists of four staves. The top two staves are in treble clef, and the bottom two are in bass clef. Each staff has a '2' written above it, indicating a specific performance style or interpretation. The music is in 2/4 time. The first measure shows a dotted half note followed by a quarter note. The second measure shows a dotted half note followed by a red circled '4'. The third measure shows a red circled '9'. The fourth measure shows a dotted half note followed by a red circled '8'. The fifth measure shows a dotted half note followed by a red circled '7'. The sixth measure shows a red circled '6'. The notes are primarily black, except for the circled numbers which are red.

Query:

A single staff in G major (two sharps) and 8/8 time. It features a bass clef and a bass staff. The staff begins with a bass clef, followed by a bass note, then a treble clef, and another bass note. This pattern repeats once.

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

153

Query:



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

Demo

The screenshot shows a digital interface for analyzing musical scores. At the top, there's a navigation bar with tabs for 'PatternFinder', 'View', and 'Visual'. Below the navigation bar is a sidebar containing a list of patterns:

- 1 Pattern
- 1 Generated
- 2411
- 444-0
- 5 -
- 6 4C 8 8 10
- 7 6B - T 3 - 8B

The main area is divided into two sections: 'Soprano' on the left and 'Alto' on the right. The 'Soprano' section displays a musical score for 'Tu es Petrus (1601) Credo à 6' in 3/4 time, treble clef, and G major. The 'Alto' section displays a musical score for 'Dies sanctificatus Credo à 4' in 3/4 time, bass clef, and C major. Both sections show musical notation with red highlights on specific notes. A toolbar at the bottom of the main area includes icons for zoom, selection, and other editing functions.

Powered by Vivaldi Humdrum Viewer and Ace text editor

#23 Occurrences

Tu es Petrus (1601) Credo à 6

123

123

Powered by Vivaldi Humdrum Viewer and Ace text editor

#23 Occurrences

Dies sanctificatus Credo à 4

123

123

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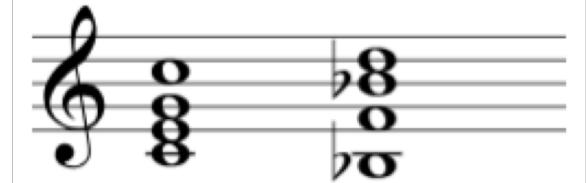
Credo Movement of Missa Tu es Petrus à 6: four intervening notes

144

Treble Clef, Common Time (4/4)

Bass Clef, Common Time (4/4)

Query:

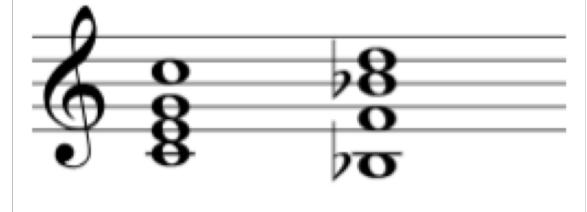


Credo Movement of Missa Tu es Petrus à 6: four intervening notes

144

The musical score shows six staves of music. The first four staves are in treble clef and common time (indicated by a '4'). The fifth staff is in bass clef and common time. The sixth staff is in bass clef and common time. Red and blue markings are present on the notes in the first four staves.

Query:



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

155

Query:



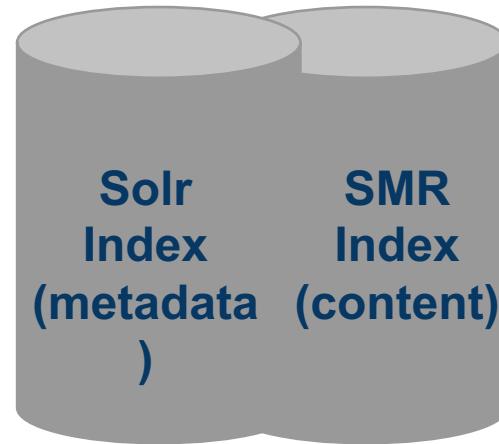
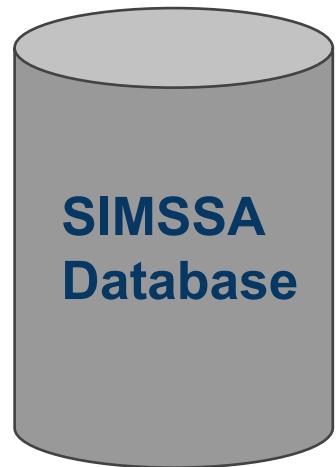
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- **Query:** written in the digital music representation “**kern”
- **Search:** An algorithm to find occurrences of our musical passage
- **Filters:** to expand or narrow search results

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

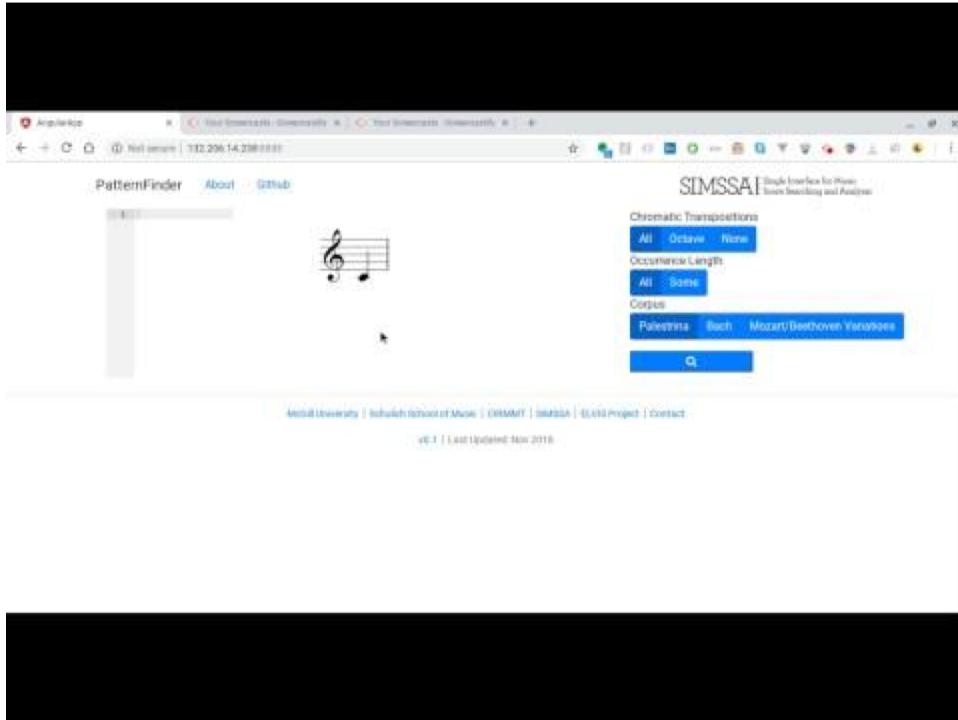
Symbolic music retrieval: desirable traits

- 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

Query:

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

Query A2 in *Spem in alium*

Query A2

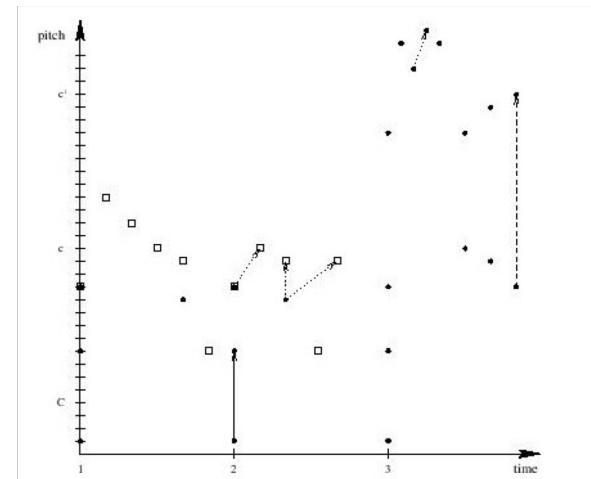
Tenor Bass Soprano Alto Tenor Bass

Puis - que j'ay per - du mon a
per - - - du

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, 2011

Unscaled similarity: queries A and B

A musical score excerpt from Schubert's *Der Leiermann*. The score consists of three staves: Treble, Bass, and Alto. The Treble staff has a key signature of one sharp. The Alto staff has a key signature of two sharps. The Bass staff has a key signature of one sharp. The music is in common time. There are five purple arrows pointing to specific notes in the Treble staff. The lyrics "drecht, und seine Leier steht ihm nimmer still," are written below the Treble staff.

Excerpt from Schubert's *Der Leiermann*

	All notes	One missing
Unscaled		

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

Unscaled similarity: queries A and B

A musical score excerpt from Schubert's *Der Leiermann*. The score consists of three staves: Treble, Bass, and Alto. The Treble staff has a key signature of one sharp. The Alto staff has a key signature of two sharps. The Bass staff has a key signature of one sharp. The music is in common time. There are several purple arrows pointing to specific notes in the Treble staff. One red arrow points to a note in the Alto staff. The lyrics "drecht, und seine Leier steht ihm nimmer still," are written below the Treble staff.

Excerpt from Schubert's *Der Leiermann*

	All notes	One missing
Unscaled		
	P5	-----> m3

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

Scaled similarity: queries C and D

A musical score excerpt from Schubert's *Der Leiermann*. The score consists of two staves: a treble clef staff and a bass clef staff. The treble clef staff has a key signature of one sharp (F#) and a time signature of 2/4. The bass clef staff has a key signature of one sharp (F#) and a time signature of 4/4. The lyrics "drecht, und seine Leier steht ihm nimmer still," are written below the treble clef staff. Five purple arrows point to specific notes in the treble clef staff: the first note of the first measure, the second note of the second measure, the third note of the third measure, the fourth note of the fourth measure, and the eighth note of the fifth measure.

Excerpt from Schubert's *Der Leiermann*

A comparison of musical queries. On the left, under the heading "Unscaled", are four queries labeled A, B, C, and D. Each query is a short musical phrase consisting of two measures. Query A starts with a G clef and a key signature of one flat (B-flat). Query B starts with a G clef and a key signature of one sharp (F#). Query C starts with a G clef and a key signature of one sharp (F#). Query D starts with a G clef and a key signature of one sharp (F#). On the right, under the heading "Scaled", are the same four queries, labeled C and D. The queries have been scaled to match the key signature and time signature of the Schubert excerpt. The scaled queries are identical to the unscaled ones except for their key signatures and time signatures.

- 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

A musical score excerpt from Schubert's *Der Leiermann*. The score consists of two staves: a treble clef staff and a bass clef staff. The treble staff has a key signature of one sharp (F#) and a common time signature. The bass staff has a key signature of one sharp (F#) and a common time signature. The lyrics "drecht, und seine Leier steht ihm nimmer still," are written below the treble staff. Five purple arrows point to specific notes in the treble staff: the first note of the first measure, the second note of the second measure, the third note of the third measure, the fourth note of the fourth measure, and the eighth note of the fifth measure.

Excerpt from Schubert's *Der Leiermann*

	All notes	One missing
Unscaled		
Scaled		
Warped		

- 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

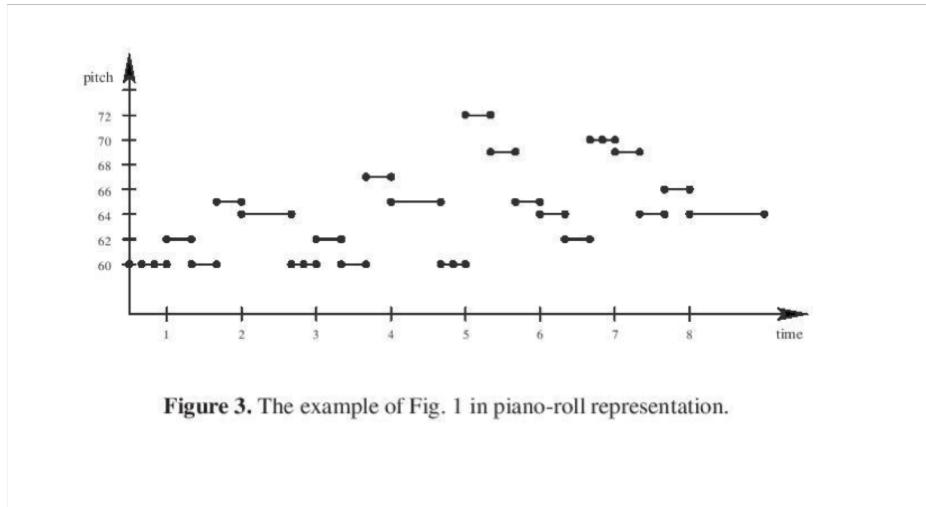
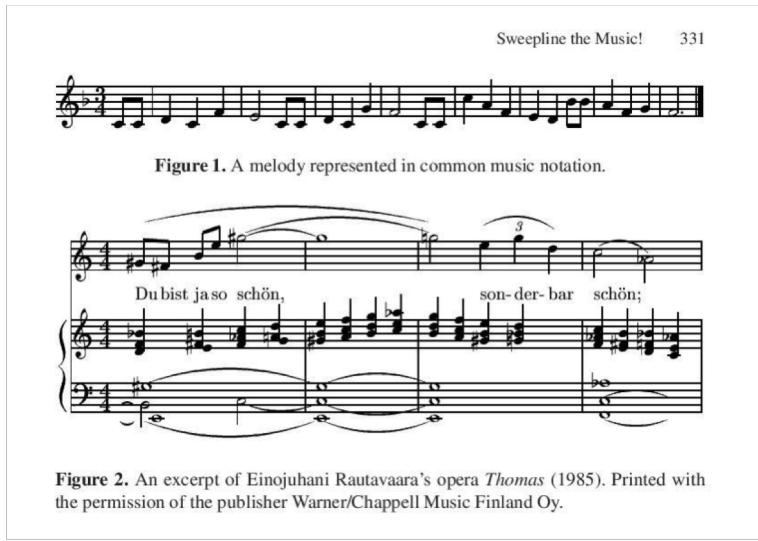
A musical score excerpt from Schubert's *Der Leiermann*. The score consists of two staves: a treble clef staff and a bass clef staff. The key signature is A major (no sharps or flats). The time signature is common time (indicated by '4'). The lyrics "drecht, und seine Leier steht ihm nimmer still," are written below the treble staff. Five purple arrows point to specific notes in the melody: the first note of the first measure, the second note of the first measure, the first note of the second measure, the second note of the second measure, and the first note of the third measure.

Excerpt from Schubert's *Der Leiermann*

	All notes	One missing
Unscaled		
Scaled		
Warped		

- 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



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

Threshold

A musical score excerpt from Schubert's *Der Leiermann*. The score consists of three staves: Treble, Bass, and a lower staff. The key signature is A major (no sharps or flats). The time signature is common time (indicated by '4'). The lyrics "drecht, und seine Leier steht ihm nimmer still," are written below the Treble staff. Five purple arrows point downwards from the top of the page towards the lyrics. A single purple arrow points downwards from the bottom of the lyrics towards the beginning of the piano part (the rightmost staff).

Excerpt from Schubert's *Der Leiermann*

Six musical queries labeled A through F, each consisting of two measures of music. The queries are arranged in two columns. The first column contains measures A and C. The second column contains measures B, D, and E. The third column contains measure F.

- Query A: Treble staff has eighth-note pairs. Bass staff has quarter notes.
- Query B: Treble staff has eighth-note pairs. Bass staff has eighth-note pairs.
- Query C: Treble staff has eighth-note pairs. Bass staff has eighth-note pairs.
- Query D: Treble staff has eighth-note pairs. Bass staff has eighth-note pairs.
- Query E: Treble staff has eighth-note pairs. Bass staff has eighth-note pairs.
- Query F: Treble staff has eighth-note pairs. Bass staff has eighth-note pairs.

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

A musical score excerpt from Schubert's *Der Leiermann*. The score consists of two staves: a treble clef staff and a bass clef staff. The key signature is one sharp (F#). The lyrics "drecht, und seine Leier steht ihm nimmer still." are written below the treble staff. Purple arrows point to specific notes: a series of eighth notes on the treble staff and a sixteenth-note figure on the bass 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'

Six musical queries labeled A through F, each consisting of a single measure on a treble clef staff. The measures are in common time. The notes in each measure are: A (E, F#, G, A), B (E, F#, G, A), C (D, E, F, G), D (D, E, F, G), E (E, F#, G, A), and F (E, F#, G, A). The measure for query D is annotated with purple arrows pointing to the notes F# and G.

Window

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

Window

A musical score excerpt in 3/4 time. The top staff shows a melody with a window of 4 notes highlighted by five purple arrows above the notes. The lyrics "drecht, und seine Leier steht ihm nimmer still." are written below the melody. The bottom staff shows harmonic bass notes.

Six musical patterns labeled A through F:

- A:** Treble clef, key signature of one flat, 3/4 time. Pattern: quarter note, eighth note, eighth note, quarter note.
- B:** Treble clef, key signature of one sharp, 3/4 time. Pattern: eighth note, eighth note, eighth note, quarter note.
- C:** Treble clef, key signature of one flat, 3/4 time. Pattern: eighth note, eighth note, eighth note, eighth note.
- D:** Treble clef, key signature of one sharp, 3/4 time. Pattern: eighth note, eighth note, eighth note, eighth note.
- E:** Treble clef, key signature of one flat, 3/4 time. Pattern: eighth note, eighth note, eighth note, quarter note.
- F:** Treble clef, key signature of one sharp, 3/4 time. Pattern: eighth note, eighth note, eighth note, quarter note.

Purple arrows highlight specific windows of 4 notes in patterns A and B.

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