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C-Brahms Research Group

Content-Based Retrieval and Analysis of Harmony and other Music Structures

1. Content-Based Music Retrieval

Content-Based Music (Information) Retrieval, CBMR (at times referred to as MIR), is a research topic that has been studied rather extensively during the last half a decade. One of its famous instances is the so-called "query by humming" or WYHIWYG (What You Hum Is What You Get) application. Given a large database of music, the task is to find those pieces of music that contain excerpts mostly resembling (in a musical way) the hummed query.

The C-BRAHMS project aims at designing and developing efficient methods for computational problems arising from music comparison, retrieval, and analysis. Particularly, the project concentrates on retrieving polyphonic music in large scale music databases containing symbolically encoded music. The project uses the findings in musicology and music psychology to achieve musically meaningful methods and results. Moreover, all the project output is planned to be exhibited in a freely available (under the GNU General Public License) query engine.

C-Brahms Group

The C-BRAHMS project was formally established in January, 2002. C-BRAHMS is a subproject to Combinatorial Pattern Matching and Information Retrieval (CPM) within the From Data to Knowledge (FDK) research unit jointly hosted by the Department of Computer Science at the University of Helsinki, and the Laboratory of Computer and Information Science at Helsinki University of Technology. FDK has been selected as one of the centres of excellence by the Academy of Finland for the period 2002-2007.

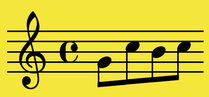
The group collaborates with several researchers and research groups abroad: the Intelligent Sound and Music Systems group at City University, London (headed by Dr. Geraint Wiggins), the Algorithm Design Group at King's College, London (headed by Prof. Costas Iliopoulos), for instance.

1. Problem setting

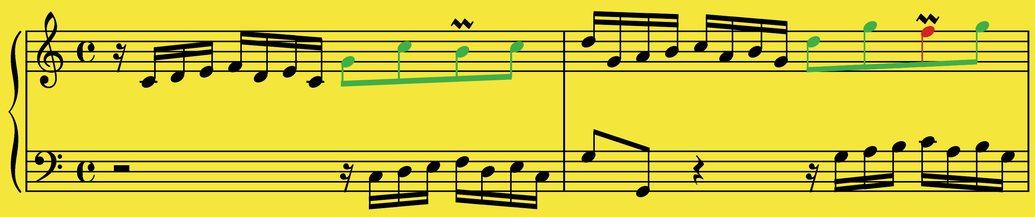
The task is to find occurrences of a pattern (1a) in a polyphonic source (1b). In this example two transposed occurrences are given in green colour. The former is a complete match, the latter a partial match with one error (the note given in red colour).

Symbolic musical data may be represented e.g. as strings or as geometric point sets. In the C-BRAHMS group, algorithms for both representations have been developed.

1a. Pattern

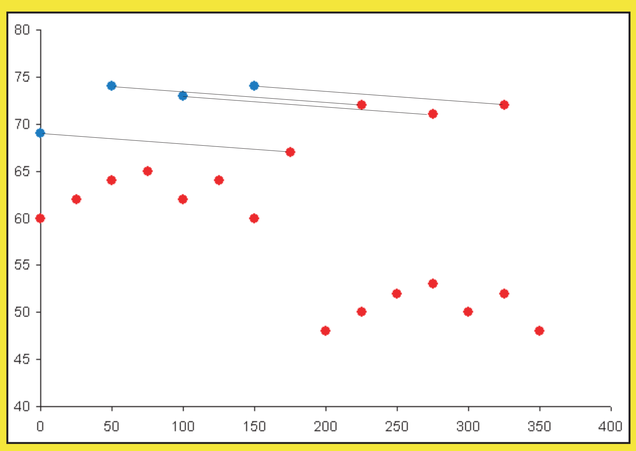


1b. Score



2. Geometric representation

In geometric representation both pattern and source are presented as points in a multidimensional space (e.g. time-pitch space below). In the example below, pattern is represented with blue colour and source with red colour.
For example SIA(M)E algorithm (Wiggins et al. 2002) calculates difference vectors between each source point and pattern point, sorts the vectors, and calculates the frequency of all such difference vectors. For instance, there is a complete match, if the frequency of some difference vector equals the number of points in the pattern.
Algorithms P1 and P2 (Ukkonen et al. 2003) are applicable for the same problem with somewhat better performances.



3. String representation

The conventional string matching techniques can be used in finding occurrences of the pattern separately from each track (as in Fig. 1b).

In polyphonic music, however, the occurrences may be distributed across the tracks. We have developed string matching methods for finding such occurrences as well (Lemström 2000, Lemström and Tarhio 2003, and Lemström and Mäkinen 2003).

3a. Pattern

```
a5 d6 c#6 d6
69 74 73 74
```

3b. Source (first bar)

```
Track 1:  c5 d5 e5 f5 d5 e5 c5 g5 -  c6 -  b5 -  c6 -
          60 62 64 65 62 64 60 67 -  72 -  71 -  72 -
Track 2:  -  -  -  -  -  -  -  -  c4 d4 e4 f4 d4 e4 c4
          -  -  -  -  -  -  -  -  48 50 52 53 50 52 48
```

3. Summary

* New state of the art geometric polyphonic algorithms
* Also fast bit-parallel polyphonic string matching based algorithms
* Demo search engine at http://www.cs.helsinki.fi/group/cbrahms

4. Recent publications

Costas Iliopoulos, Kjell Lemström, Mohammed Niyad, and Yoan Pinzon: Evolution of Musical Motifs in Polyphonic Passages. *Proc. AISB'2002 Symposium on AI and Creativity in Arts and Science, pp. 67 - 75, London, United Kingdom, April 2-5, 2002.*
Kjell Lemström: Polyfonisen musiikin haku sisällön perusteella. *Tietojenkäsittelytiede, (17), 48-65, 2002.*
Anna Pienimäki: What you hum is what you get! - musiikkitiedonhaun lyhyt oppimäärä. *Synkooppi op. 66, 1 (2002), pp. 20-22.*
Anna Pienimäki: Indexing Music Databases Using Automatic Extraction of Frequent Phrases. *Proc. ISMIR'02 Third International Conference on Music Information Retrieval , Paris, France, October 13-17, 2002, pp. 25-30.*
Geraint A. Wiggins, Kjell Lemström and David Meredith: SIA(M)ESE: An Algorithm for Transposition Invariant, Polyphonic Content-Based Music Retrieval. *Proc. ISMIR'02 Third International Conference on Music Information Retrieval , pp. 283-284, Paris, France, October 13-17, 2002.*
Kjell Lemström and Lauri Hella: Approximate Pattern Matching and Transitive Closure Logics. *Theoretical Computer Science, 299(1-3), 387-412, 2003 (to appear).*
David Meredith, Kjell Lemström and Geraint A. Wiggins: Algorithms for Discovering Repeated Patterns in Multidimensional Representations of Polyphonic Music. *Journal of New Music Research, 31(4), 321-345 (to appear).*
Kjell Lemström: Content-Based Retrieval of Symbolic Music. *In Proc. FSKD'02 1st International Conference on Fuzzy Systems and Knowledge Discovery, pp. 401-405, Singapore, November 18-22, 2002.*
Esko Ukkonen, Kjell Lemström, and Veli Mäkinen: Sweepline the music! *In Computer Science in Perspectiv, R. Klein, H.-W. Six, L. Wegner (Eds.), Springer-Verlag LNCS VOL. 2598, pp. 330-342, February, 2003.*
Veli Mäkinen, Gonzalo Navarro, and Esko Ukkonen: Algorithms for Transposition Invariant String Matching. *In Proc. 20th International Symposium on Theoretical Aspects of Computer Science (STACS 2003), Springer-Verlag LNCS VOL. 2607, pp. 191-202, Berlin, February, 2003.*
Kjell Lemström and Veli Mäkinen: On Finding Minimum Splitting of Pattern in Multi-Track String Matching. *To appear in Proc. 14th Annual Symposium on Combinatorial Pattern Matching (CPM 2003), Morelia, Mexico, June 25-27, 2003.*
Kjell Lemström and Jorma Tarhio: Transposition invariant pattern matching for multi-track strings. *Submitted for publication.*

5. Theses

Kjell Lemström: String Matching Techniques for Music Retrieval. *PhD thesis, A-2000-4, University of Helsinki, Department of Computer Science, November 2000.*
Anna Pienimäki: Musiikillisen datan indeksointi maksimaalisia fraaseja käyttäen (Indexing musical data using maximal phrases). *MSc thesis (in Finnish), C-2002-30, University of Helsinki, Department of Computer Science, March 2002.*

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