Music 254/CS 275b

Music Query, Analysis, and Style Simulation

- 2–4 Credits
- MW 1:15–3:05, Braun Music Building 128
- Eleanor Selfridge-Field (esfield @ stanford.edu)
- Craig Sapp (craigsapp @ stanford.edu)
- Website: http://music254.stanford.edu (http://254.ccarh.org)

- Grading: 25% class participation, 75% project
- Deadlines:
  - Project proposal, 3 pages, Wed. 17 April 2013 (end of week 3)
  - Project presentation, 20–30 minutes, Wed. 5 June 2013
  - Project writeup draft, 5+ pages, Wed. 5 June 2013
  - Project writeup, 10–20 pages, Wed. 12 June 2013

- First month: concentration on Humdrum data and tools:
  - harmony, melody, rhythm, regular expressions, data conversion
- Second month: concentration on project research/development
  - Literature reports & project updates by students

Class info (2)

- No class on May 20 & 22 (and possibly 27th)
  - Music Encoding Conference, Mainz, Germany
  - http://music-encoding.org/conference/program

- ISMIR paper deadline: 10 May 2013 (http://www.ppgia.pucpr.br/ismir2013)
- ICMC (http://icmc2013.com.au) August 11-17 (submission date passed)
- ACM various conferences (http://www.acm.org/conferences)

- Josquin Research Project concert and workshop (13 & 14 April)
  http://music.stanford.edu/Events/josquin.html
  Sign up if interested in attending workshop.
- Project idea: style analysis in early Renaissance music (http://jrp.ccarh.org)

Harmony Tools in Humdrum

craigsapp@stanford.edu

1/3 April 2013

1. Intervals

hint: harmonic intervals

2. Chords

tntype: sonority types

3. Key

key/**keycor**: musical key by correlation

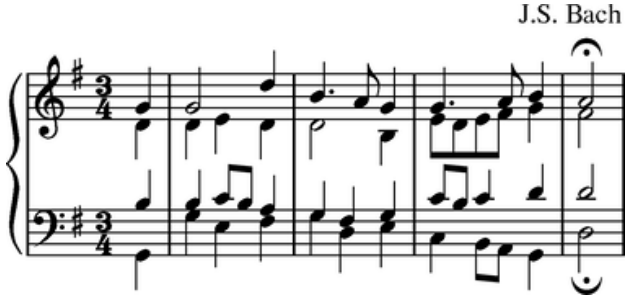
hint

```
humcat h://371chorales/chor001.krn > chor001.krn
hint chor001.krn > hint.txt
assemble chor001.krn hint.txt > chor001.hint
```

(Save a local copy of chorale 1)

(Save output from hint)

(Merge hint data with original score)




```
!!!COM:      Bach, Johann Sebastian
!!!CDT:      1685/02/21/-1750/07/28/
!!!OTL@@DE: Aus meines Herzens Grunde
!!!OTL@EN:  From the Depths of My Heart
!!!SCT:      BWV 269
**kern       **kern       **kern       **kern       **hint
*Ibass       *Itenor      *Ialto       *Isoprn      *
*clefF4      *clefGv2     *clefG2      *clefG2      *
*k[f#]       *k[f#]       *k[f#]       *k[f#]       *k[f#]
*G:          *G:          *G:          *G:          *G:
*M3/4        *M3/4        *M3/4        *M3/4        *M3/4
4GG          4B           4d           4g           M10 m3 P4
=1           =1           =1           =1           =1
4G           4B           4d           2g           M3 m3 P4
4E           8cL          4e           .            m6 M3
.            8BJ          .            .            -
4F#          4A           4d           4dd          m3 P4 P8
=2           =2           =2           =2           =2
4G           4G           2d           4.b          P1 P5 M6
4D           4F#          .            .            M3
.            .            .            8a           -
4E           4G           4B           4g           m3 M3 m6
```

```
satb2gs file.krn | autostem | hum2muse \
  | muse2ps =z21v120,120c120T^^ \
  | pstopnm -dpi=300 | convert - -trim \
    -resize '33%' file.png
```

Humdrum program documentation

hint –h	gives one-page summary of *hint* command (similar for all Humdrum Toolkit programs)
serialize --options	list options for serialize command (same for all Humdrum Extras programs)

Humdrum Toolkit man pages:
http://www.humdrum.org/Humdrum/commands/hint.html

Humdrum Extras man pages:
http://extras.humdrum.org/man/serialize

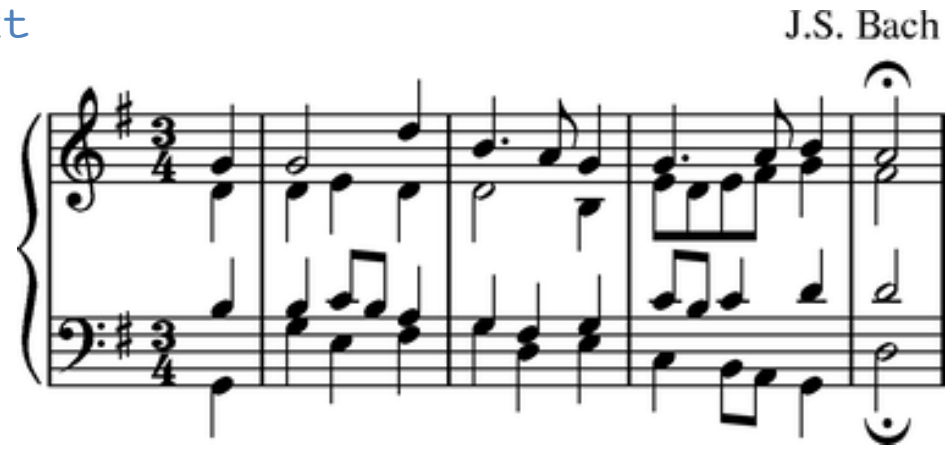
Chapter 15 in the Humdrum Users' Guide (Harmonic Intervals):
http://www.humdrum.org/Humdrum/guide15.html

List of various Humdrum resources:
http://humdrum.ccarh.org

hint -a

- -a option shows intervals for all note permutations, not just “stacked intervals”

```
hint –a chor001.krn > hinta.txt
```

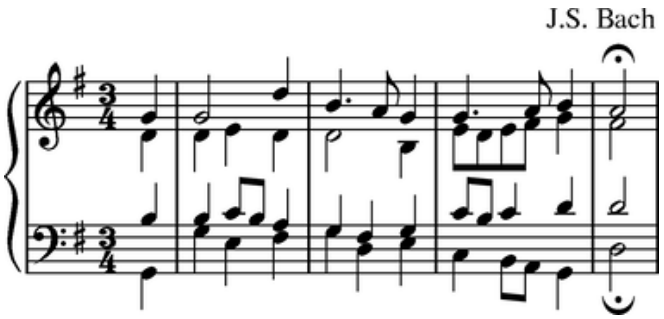



```
!!!COM: Bach, Johann Sebastian
!!!CDT: 1685/02/21/-1750/07/28/
!!!OTL@@DE:      Aus meines Herzens Grunde
!!!OTL@EN:       From the Depths of My Heart
!!!SCT: BWV 269
**kern   **kern   **kern   **kern   **hint
*Ibass   *Itenor  *Ialto   *Isoprn  *
*clefF4  *clefG2  *clefG2  *clefG2  *
*k[f#]   *k[f#]   *k[f#]   *k[f#]   *k[f#]
*G:      *G:      *G:      *G:      *G:
*M3/4    *M3/4    *M3/4    *M3/4    *M3/4
4GG      4B       4d       4g       M10 P12 P15 m3 m6 P4
=1       =1       =1       =1       =1
4G       4B       4d       2g       M3 P5 P8 m3 m6 P4
4E       8cL      4e       .        m6 P8 M3
.        8BJ      .        .        -
4F#      4A       4d       4dd      m3 m6 m13 P4 P11 P8
=2       =2       =2       =2       =2
4G       4G       2d       4.b      P1 P5 M10 P5 M10 M6
4D       4F#      .        .        M3
.        .        .        8a       -
4E       4G       4B       4g       m3 P5 m10 M3 P8 m6
```

hint -c

- Collapse the interval to a single octave. Such as: P12 → P8+P4 → P4

```
hint –ac chor001.krn > hinta.txt
hint –a -c chor001.krn > hintac.txt
```

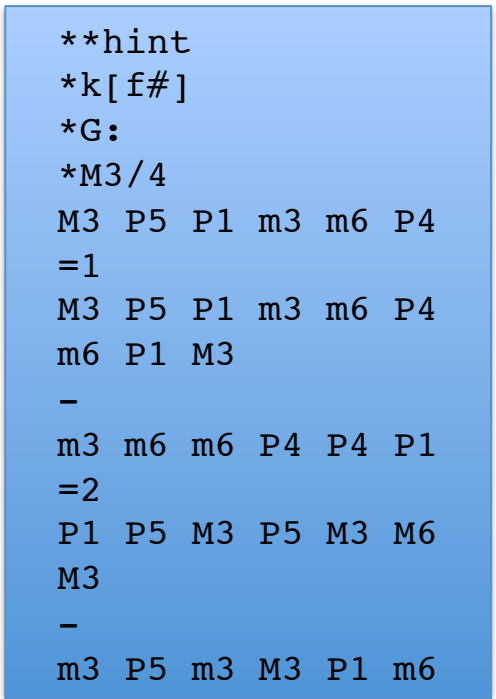


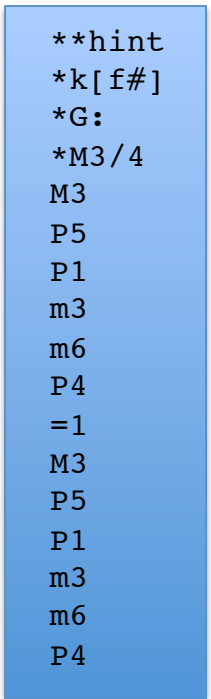
**kern	**kern	**kern	**kern	**hint
*Ibass	*Itenor	*Ialto	*Isoprn	*
*clefF4	*clefGv2	*clefG2	*clefG2	*
*k[f#]	*k[f#]	*k[f#]	*k[f#]	*k[f#]
*G:	*G:	*G:	*G:	*G:
*M3/4	*M3/4	*M3/4	*M3/4	*M3/4
4GG	4B	4d	4g	M3 P5 P1 m3 m6 P4
=1	=1	=1	=1	=1
4G	4B	4d	2g	M3 P5 P1 m3 m6 P4
4E	8cL	4e	.	m6 P1 M3
.	8BJ	.	.	-
4F#	4A	4d	4dd	m3 m6 m6 P4 P4 P1
=2	=2	=2	=2	=2
4G	4G	2d	4.b	P1 P5 M3 P5 M3 M6
4D	4F#	.	.	M3
.	.	.	8a	-
4E	4G	4B	4g	m3 P5 m3 M3 P1 m6
=3	=3	=3	=3	=3
4C	8cL	8eL	4.g	P1 M3 P5 M3 P5 m3
.	8BJ	8d	.	m3
8BBL	4c	8e	.	m2 P4 M3
8AAJ	.	8f#J	8a	M6 P1 m3
4GG	4d	4g	4b	P5 P1 M3 P4 M6 M3

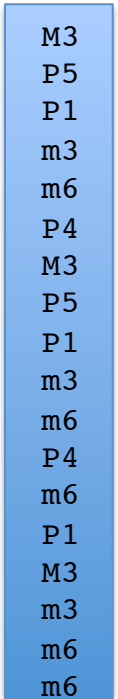
Most common harmonic interval

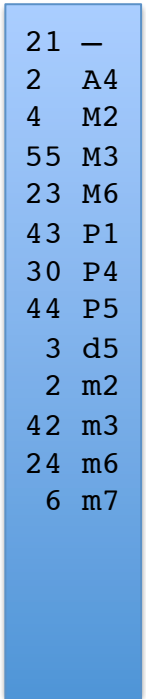
hint –ac chor001.krn | serialize –c | ridx –H | sort | uniq –c | sort -nr

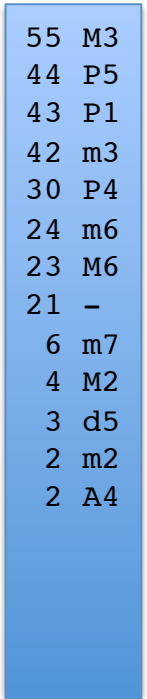
1. hint –ac chor001.krn: do harmonic interval analysis (Humdrum Toolkit)
2. serialize –c: force intervals one to a line (Humdrum Extras)
3. ridx –H: remove Humdrum file structure from data (Humdrum Extras)
4. sort: sort lines alphabetically (Unix)
5. uniq –c: output lines without repetitions, counting occurrences (Unix)
6. sort –nr: sort numerically, in reverse order (largest count first) (Unix)









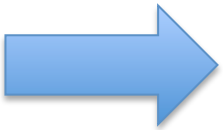


ditto

- *hint* ignores null tokens, resulting in harmonic intervals between note attacks only
- To also include intervals to sustained intervals from previous attacks, use *ditto*
- This fills in the null token with the continuing data token it represents

ditto chor001.krn

**kern	**kern	**kern	**kern
*Ibass	*Itenor	*Ialto	*Isoprn
*clefF4	*clefG2	*clefG2	*clefG2
*k[f#]	*k[f#]	*k[f#]	*k[f#]
*G:	*G:	*G:	*G:
*M3/4	*M3/4	*M3/4	*M3/4
4GG	4B	4d	4g
=1	=1	=1	=1
4G	4B	4d	2g
4E	8cL	4e	.
.	8BJ	.	.
4F#	4A	4d	4dd
=2	=2	=2	=2
4G	4G	2d	4.b
4D	4F#	.	.
.	.	.	8a
4E	4G	4B	4g



**kern	**kern	**kern	**kern
*Ibass	*Itenor	*Ialto	*Isoprn
*clefF4	*clefG2	*clefG2	*clefG2
*k[f#]	*k[f#]	*k[f#]	*k[f#]
*G:	*G:	*G:	*G:
*M3/4	*M3/4	*M3/4	*M3/4
4GG	4B	4d	4g
=1	=1	=1	=1
4G	4B	4d	2g
4E	8cL	4e	**2g**
4E	8BJ	**4e**	**2g**
4F#	4A	4d	4dd
=2	=2	=2	=2
4G	4G	2d	4.b
4D	4F#	**2d**	**4.b**
4D	**4F#**	**2d**	8a
4E	4G	4B	4g

Most common harmonic interval including sustained notes

hint –ac chor001.krn | serialize –c | ridx –H | sort | uniq –c | sort -nr

ditto chor001.krn | hint –ac | serialize –c | ridx –H | sort | uniq –c | sort -nr

attacks

```
55 M3
44 P5
43 P1
42 m3
30 P4
24 m6
23 M6
21 -
 6 m7
 4 M2
 3 d5
 2 m2
 2 A4
```

+sustains

```
76 P5
75 M3
74 m3
59 P1
56 P4
43 M6
41 m6
18 m7
16 M2
 9 A4
 7 d5
 4 m2
 2 M7
```

All Bach chorales

download and save all 370 chorales locally:

humcat –s h://371chorales > 371chorales.krns (one file containing all chorales)
humcat –s h://371chorales | humsplit (separate each chorale into a separate file)

hint –ac 371chorales.krns | serialize –c | ridx –H | sort | uniq –c | sort -nr

ditto 371chorales.krns | hint –ac | serialize –c | ridx –H | sort | uniq –c | sort -nr

```
18053 m3
17545 P5
16147 M3
15263 P1
10812 P4
10035 M6
 9935 m6
 2537 M2
 1542 m7
 1534 A4
 1103 d5
  397 m2
  248 M7
  175 d7
   64 A2
   62 d4
   43 A5
    2 A6
    1 d1
```

Beethoven string quartets

download and save all quartets locally:

humcat –s h://beethoven/quartets > beethoven-quartets.krns

or humcat –s h://beethoven/quartests | humsplit

hint –ac beethoven-quartets.krns | serialize –c | ridx –H | sort | uniq –c | sort -nr

ditto beethoven-quartets.krns | hint –ac | serialize –c | ridx –H | sort | uniq –c | sort -nr

```
60156 P1
 40163 m3        269 A6
 31479 M3        104 A1
 26374 P5         80 d6
 24285 M6         67 d3
 21775 P4         55 d1
 18348 m6         39 A3
 10697 m7         27 AA4
  9520 M2         23 d2
  7491 A4         18 A7
  6559 d5         10 dd5
  2237 M7          7 dd1
  1659 A2          7 AA2
  1419 m2          5 dd7
  1395 d7          2 dd4
   529 A5          2 AA5
   431 d4
```

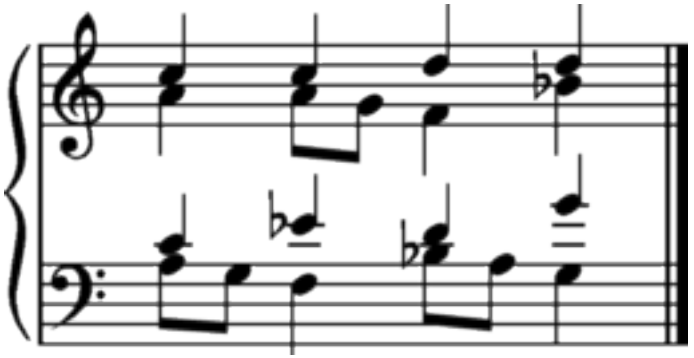
```
102597 P1
 69409 m3        403 A1
 57966 M3        223 d1
 55746 P5        147 d6
 46270 M6        121 A3
 45913 P4        113 d3
 35295 m6         72 d2
 23213 m7         40 A7
 22159 M2         37 AA4
 14037 A4         34 dd5
 12924 d5         15 dd1
  6139 M7         13 dd7
  4529 m2         13 AA2
  3020 A2          3 dd4
  2764 d7          3 AA5
  1453 A5          1 AA6
  1155 d4          1 AA3
   533 A6          1 AA1
```

tntype

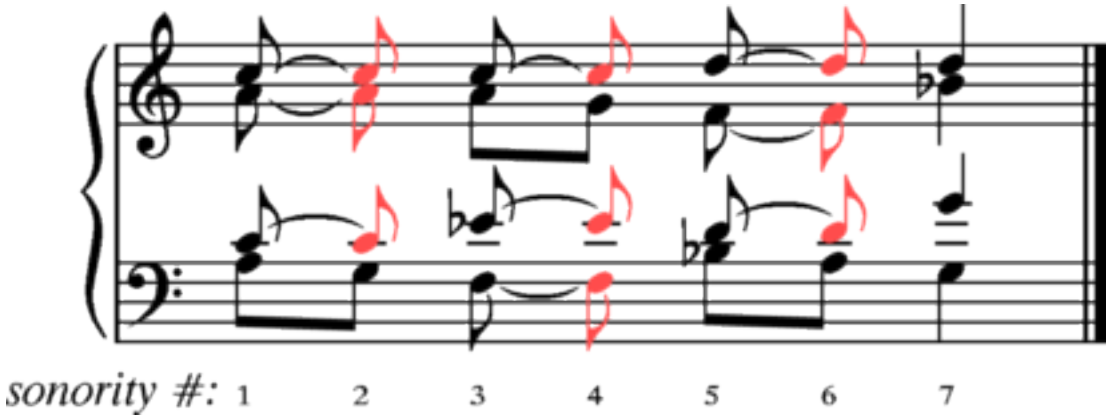
Tool for generalized description of sonority types (pitch-class sets sounding together)

documentation: http://extras.humdrum.org/man/tntype

similar to Humdrum Toolkit command pcset http://www.humdrum.org/Humdrum/commands/pcset.html

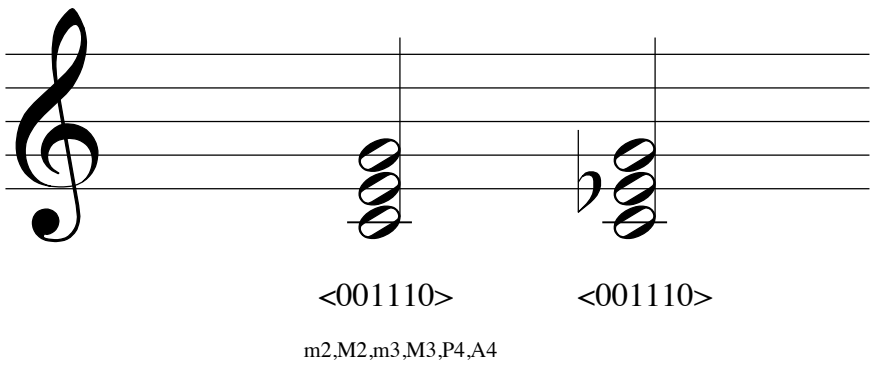


seven successive “sonorities” present in the above music:



Interval vectors

- Similar data generated by *hint*, but more compact

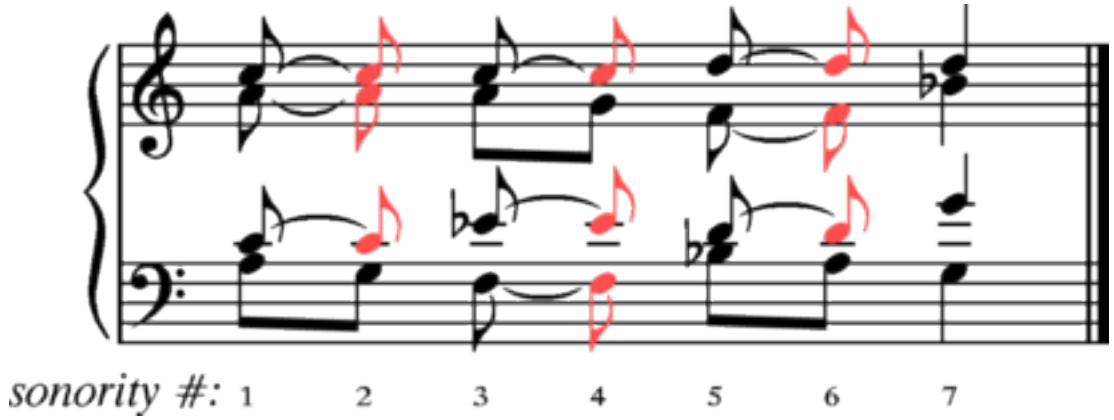


- Major and minor triads have the same interval content: m3, M3, P5
- <001110> is can be represented by the Forte number enumeration 3-11.
  - 3 = three pitch classes in set
  - 11 = 11th most compact organization of 3 pitch classes

    3-1 = c,c#,d 3-2 = c,c#,d# 3-3 = c,c#,e 3-4 = c,c#,f 3-5 = c,c#,f# etc.

tntype -d

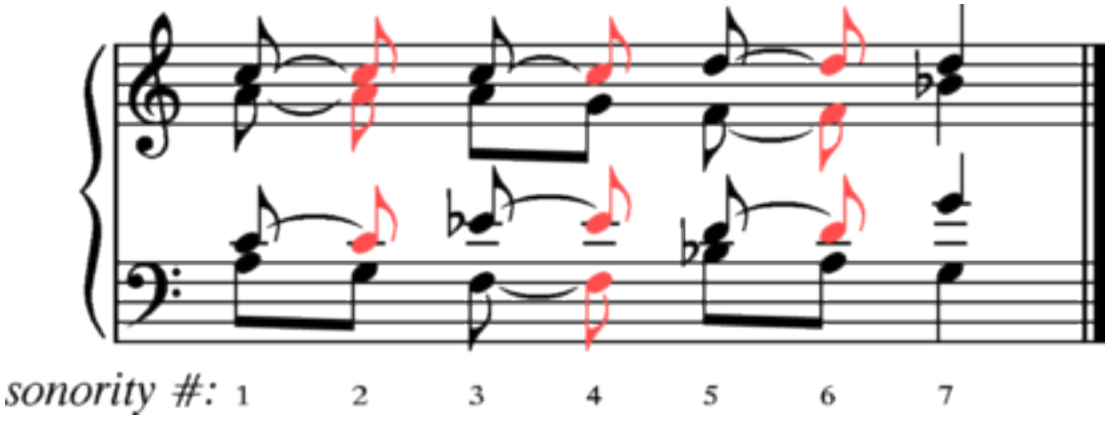
Generate a **dpc (diatonic pitch-class) spine listing unique pitch classes in sonorities



tntype –ad file.krn

```
**kern   **kern   **kern   **kern   **num   **dpc
=1-      =1-      =1-      =1-      =1-     =1-
8AL      4c       4a       4cc      1       A c
8GJ      .        .        .        2       (a) (c) G
4F       4e-      8aL      4cc      3       F a c e-
.        .        8gnXJ    .        4       (c) (e-) (F) g
8B-L     4d       4f       4dd      5       B- d f
8AJ      .        .        .        6       (d) (f) A
4G       4g       4b-      4dd      7       G b- d
==       ==       ==       ==       ==      ==
*-       *-       *-       *-       *-      *-
```

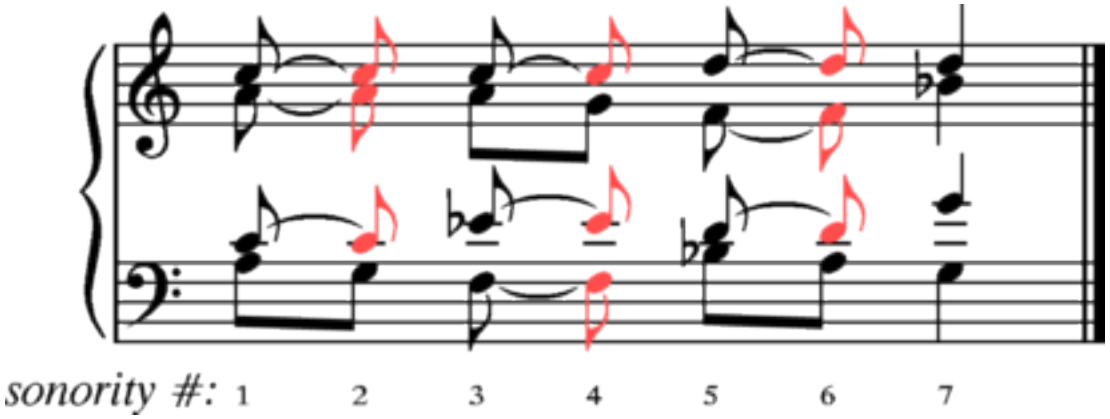
Normal form



tntype –na file.krn

```
**kern   **kern   **kern   **kern   **num    **nf
=1-      =1-      =1-      =1-      =1-      =1-
8AL      4c       4a       4cc      1        [90]
8GJ      .        .        .        2        [790]
4F       4e-      8aL      4cc      3        [9035]
.        .        8gnXJ    .        4        [0357]
8B-L     4d       4f       4dd      5        [A25]
8AJ      .        .        .        6        [259]
4G       4g       4b-      4dd      7        [7A2]
==       ==       ==       ==       ==       ==
*-       *-       *-       *-       *-       *-
```

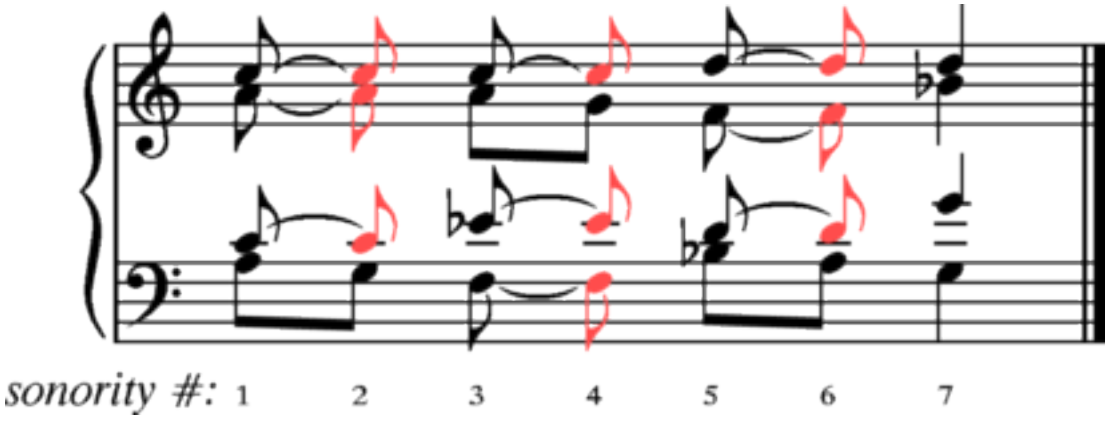
Transposed normal form



tntype –af file.krn

**kern	**kern	**kern	**kern	**num	**tnf
=1-	=1-	=1-	=1-	=1-	=1-
8AL	4c	4a	4cc	1	{03}
8GJ	.	.	.	2	{025}
4F	4e-	8aL	4cc	3	{0368}
.	.	8gnXJ	.	4	{0357}
8B-L	4d	4f	4dd	5	{047}
8AJ	.	.	.	6	{037}
4G	4g	4b-	4dd	7	{037}
==	==	==	==	==	==
*-	*-	*-	*-	*-	*-

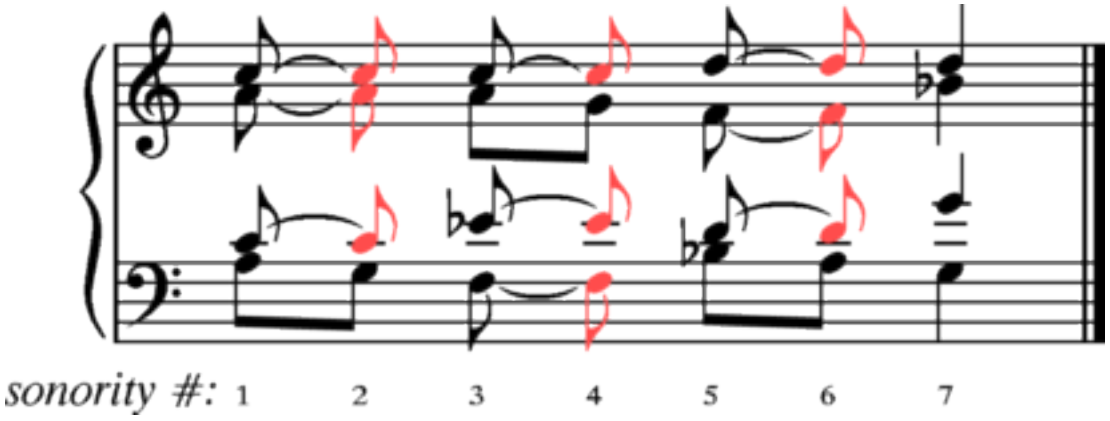
Preserving transposition



tntype –an input | tntype –aft

**kern	**kern	**kern	**kern	**num	**nf	**tnf
=1-	=1-	=1-	=1-	=1-	=1-	=1-
8AL	4c	4a	4cc	1	[90]	{03}T9
8GJ	.	.	.	2	[790]	{025}T7
4F	4e-	8aL	4cc	3	[9035]	{0368}T9
.	.	8gnXJ	.	4	[0357]	{0357}T0
8B-L	4d	4f	4dd	5	[A25]	{047}T10
8AJ	.	.	.	6	[259]	{037}T2
4G	4g	4b-	4dd	7	[7A2]	{037}T7
==	==	==	==	==	==	==
*-	*-	*-	*-	*-	*-	*-

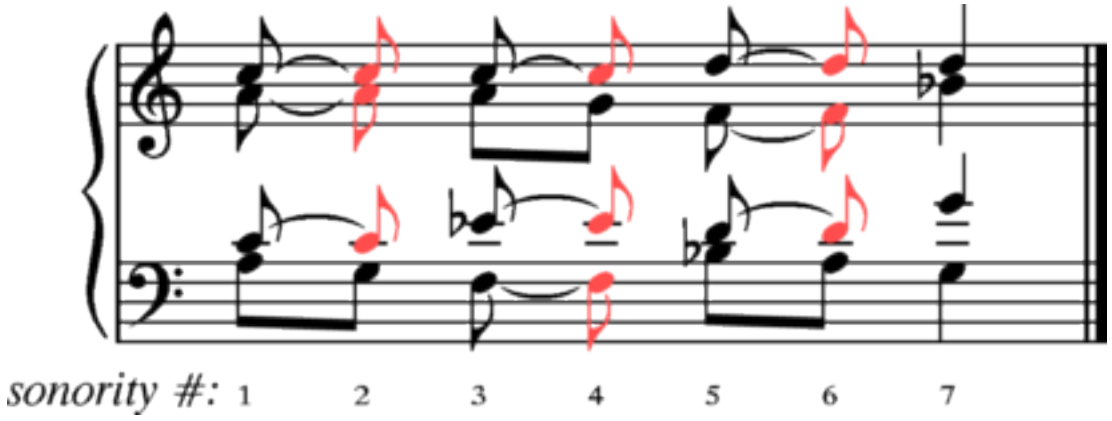
Forte pc-set enumerations



Tntype –an | tntype –aft | tntype -aF

**kern	**kern	**kern	**kern	**num	**nf	**tnf	**forte
=1-	=1-	=1-	=1-	=1-	=1-	=1-	=1-
8AL	4c	4a	4cc	1	[90]	{03}T9	2-3
8GJ	.	.	.	2	[790]	{025}T7	3-7
4F	4e-	8aL	4cc	3	[9035]	{0368}T9	4-27
.	.	8gnXJ	.	4	[0357]	{0357}T0	4-22
8B-L	4d	4f	4dd	5	[A25]	{047}T10	3-11
8AJ	.	.	.	6	[259]	{037}T2	3-11
4G	4g	4b-	4dd	7	[7A2]	{037}T7	3-11
==	==	==	==	==	==	==	==
*-	*-	*-	*-	*-	*-	*-	*-

Forte numbers, without inversions



tntype –an | tntype –aft | tntype –aF --Tn

**kern	**kern	**kern	**kern	**num	**nf	**tnf	**Tn
=1-	=1-	=1-	=1-	=1-	=1-	=1-	=1-
8AL	4c	4a	4cc	1	[90]	{03}T9	2-3
8GJ	.	.	.	2	[790]	{025}T7	3-7
4F	4e-	8aL	4cc	3	[9035]	{0368}T9	4-27
.	.	8gnXJ	.	4	[0357]	{0357}T0	4-22
8B-L	4d	4f	4dd	5	[A25]	{047}T10	3-11B
8AJ	.	.	.	6	[259]	{037}T2	3-11A
4G	4g	4b-	4dd	7	[7A2]	{037}T7	3-11A
==	==	==	==	==	==	==	==
*-	*-	*-	*-	*-	*-	*-	*-

Chord interpretations

humcat h://371chorales/chor001.krn | tntype -a | tntype -tfa | tntype -Da

**kern	**kern	**kern	**kern	**tnt	**tnf	**description
*Ibass	*Itenor	*Ialto	*Isoprn	*	*	*
*k[f#]	*k[f#]	*k[f#]	*k[f#]	*k[f#]	*k[f#]	*k[f#]
*M3/4	*M3/4	*M3/4	*M3/4	*M3/4	*M3/4	*M3/4
4GG	4B	4d	4g	3-11B	{047}T07	Major Chord
=1	=1	=1	=1	=1	=1	=1
4G	4B	4d	2g	3-11B	{047}T07	Major Chord
4E	8cL	4e	.	3-11B	{047}T00	Major Chord
.	8BJ	.	.	3-11A	{037}T04	Minor Chord
4F#	4A	4d	4dd	3-11B	{047}T02	Major Chord
=2	=2	=2	=2	=2	=2	=2
4G	4G	2d	4.b	3-11B	{047}T07	Major Chord
4D	4F#	.	.	3-11A	{037}T11	Minor Chord
.	.	.	8a	3-11B	{047}T02	Major Chord
4E	4G	4B	4g	3-11A	{037}T04	Minor Chord
=3	=3	=3	=3	=3	=3	=3
4C	8cL	8eL	4.g	3-11B	{047}T00	Major Chord
.	8BJ	8d	.	4-14B	{0457}T07	Perfect-fourth Major Tetrachord
8BBL	4c	8e	.	4-20	{0158}T11	Major-seventh Chord
8AAJ	.	8f#J	8a	3-10	{036}T06	Diminished Chord
4GG	4d	4g	4b	3-11B	{047}T07	Major Chord
=4	=4	=4	=4	=4	=4	=4

Bach chorale sonority types

- Are there more major or minor sonorities in Bach chorales?

By musical description:

```
humcat -s h://371chorales | tntype -D | ridx –H | sort | uniq -c | sort -nr
```

By Forte number:

```
humcat -s h://371chorales | tntype | ridx –H | sort | uniq -c | sort -nr
```

- What is the most common 7^{th} chord sonority?

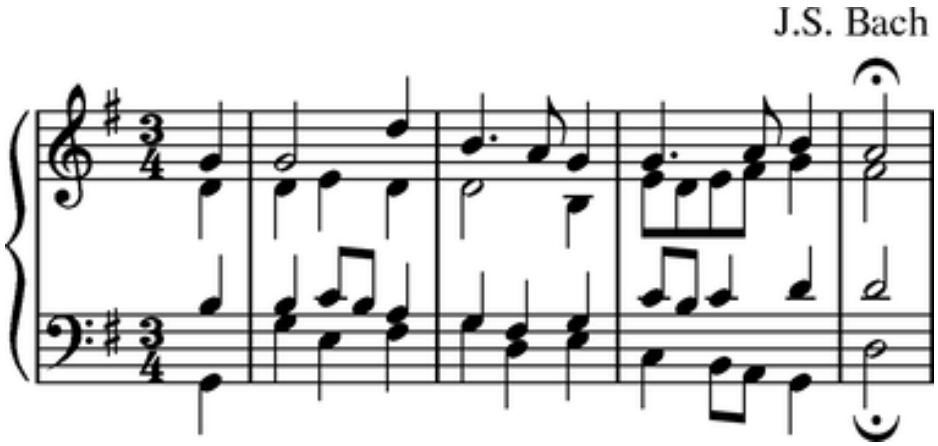
sonority

- similar to tntype program but has more triad-centered descriptions of sonorities

http://extras.humdrum.org/man/sonority

sonority -a h://371chorales/chor001.krn

**kern	**kern	**kern	**kern	**qual
*ICvox	*ICvox	*ICvox	*ICvox	*ICvox
*Ibass	*Itenor	*Ialto	*Isoprn	*
*k[f#]	*k[f#]	*k[f#]	*k[f#]	*k[f#]
*G:	*G:	*G:	*G:	*G:
*M3/4	*M3/4	*M3/4	*M3/4	*M3/4
*MM100	*MM100	*MM100	*MM100	*MM100
4GG	4B	4d	4g	maj:0:G
=1	=1	=1	=1	=1
4G	4B	4d	2g	maj:0:G
4E	8cL	4e	.	maj:1:C
.	8BJ	.	.	min:0:E
4F#	4A	4d	4dd	maj:1:D
=2	=2	=2	=2	=2
4G	4G	2d	4.b	maj:0:G
4D	4F#	.	.	min:1:B
.	.	.	8a	maj:0:D
4E	4G	4B	4g	min:0:E
=3	=3	=3	=3	=3
4C	8cL	8eL	4.g	maj:0:C
.	8BJ	8d	.	X
8BBL	4c	8e	.	majmaj:3:C
8AAJ	.	8f#J	8a	dim:1:F#
4GG	4d	4g	4b	maj:0:G
=4	=4	=4	=4	=4
2D;	2d;	2f#;	2a;	maj:0:D



Starting/Ending sonority

- Do Bach chorales start and end on the same sonority?
- How does the starting/ending chord root relate to the key of the chorale?

humcat -s h://371chorales | humsplit

```
#!/usr/bin/perl

@filelist = @ARGV;

foreach $file (@filelist) {
   processFile($file)
}

sub processFile {
  my ($file) = @_;
  $first_sonority = `sonority $file | ridx -GLIMd | grep -v "::" | head -n 1`;
  $last_sonority  = `sonority $file | ridx -GLIMd | grep -v "::" | tail -n 1`;
  $key = `egrep -i '^\\*[A-G][#-]?:' $file | head -n 1 | sed 's/\t.*//'`;
  chomp $first_sonority;
  chomp $last_sonority;
  chomp $key;
  print "$file\t$key\t$first_sonority\t$last_sonority\n";
}
```

Starting/Ending sonority (2)

chor001.krn	*G:	maj:0:G	maj:0:G
chor002.krn	*A:	maj:0:A	maj:0:A
chor003.krn	*a:dor	maj:0:E	maj:0:E
chor004.krn	*E:	maj:0:E	maj:0:E
chor005.krn	*G:	maj:0:G	maj:0:G
chor006.krn	*F:	maj:0:F	maj:0:F
chor007.krn	*A:	maj:0:A	maj:0:A
chor008.krn	*f:dor	min:0:F	maj:0:F
chor009.krn	*G:	maj:0:G	maj:0:G
chor010.krn	*a:	domsev:3:E	maj:0:E
chor011.krn	*C:	maj:0:C	maj:0:C
chor012.krn	*a:	min:0:A	maj:0:A
chor013.krn	*a:	min:0:A	maj:0:A
chor014.krn	*G:	maj:0:G	maj:0:G
chor015.krn	*d:dor	min:0:D	maj:0:D
chor016.krn	*b:	maj:0:F#	maj:0:F#
chor017.krn	*e:	min:0:E	maj:0:E
chor018.krn	*G:	maj:0:G	maj:0:G
chor019.krn	*g:dor	min:0:G	maj:0:G
chor020.krn	*D:	maj:0:D	maj:0:D
chor021.krn	*a:	domsev:3:E	maj:0:E
chor022.krn	*E-:	maj:0:E-	maj:0:E-
chor023.krn	*a:	min:0:A	maj:0:A
chor024.krn	*D:	maj:0:D	maj:0:D
chor025.krn	*f:dor	min:0:F	maj:0:F

Check for unusual cases

```
#!/usr/bin/perl

@filelist = @ARGV;

foreach $file (@filelist) {
    processFile($file)
}

sub processFile {
   my ($file) = @_;
   $first_sonority = `sonority $file | ridx -GLIMd | grep -v "::" | head -n 1`;
   $last_sonority  = `sonority $file | ridx -GLIMd | grep -v "::" | tail -n 1`;
   $key = `egrep -i '^\\*[A-G][#-]?:' $file | head -n 1 | sed 's/\t.*//'`;
   chomp $first_sonority;
   chomp $last_sonority;
   chomp $key;
   $first_sonority =~ /:([^:]*)$/;
   $first_root = $1;
   $last_sonority =~ /:([^:]*)$/;
   $last_root = $1;
   $key =~ /^\*([A-G][#-]?):/;
   $key_root = uc($1);
   if (($first_root ne $last_root) or ($first_root ne $key_root)) {
      print "$file\t$key\t$first_sonority\t$last_sonority\n";
   }
}
```

Inconsistent start/end/key

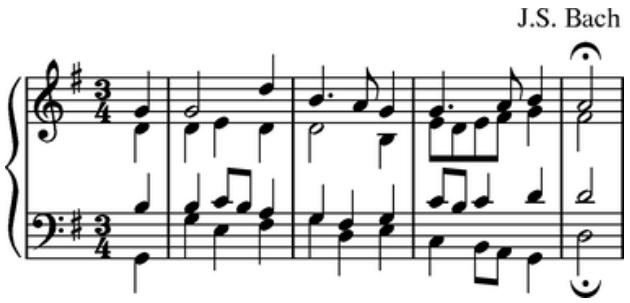
	chor056.krn	*b:	min:0:E	maj:0:F#
	chor057.krn	*a:	maj:0:E	min:0:A
	chor066.krn	*a:	min:0:D	maj:0:A
	chor071.krn	*e:	maj:1:B	maj:0:E
	chor074.krn	*F:	min:0:D	maj:0:F
	chor077.krn	*A:	min:0:F#	maj:0:A
	chor079.krn	*a:	min:0:A	maj:0:E
	chor083.krn	*A:	min:0:F#	maj:0:A
	chor089.krn	*b:	min:0:B	maj:0:F#
	chor119.krn	*c:dor	maj:0:B-	maj:0:C
	chor121.krn	*A:	min:0:F#	maj:0:A
	chor154.krn	*G:mix	min:0:D	maj:0:G
	chor162.krn	*d:dor	maj:0:A	maj:0:E
	chor181.krn	*e:	min:0:E	maj:0:B
	chor205.krn	***C:**	**min:0:E**	**maj:0:E → *e:phr**
	chor208.krn	*e:	min:0:E	maj:0:B
	chor227.krn	*d:	min:0:G	maj:0:D
	chor248.krn	*G:	maj:1:D	maj:0:G
bwv 77/6	**chor253.krn**	***g:**	**maj:0:A**	**maj:0:D**
	chor255.krn	*D:	maj:1:A	maj:0:D
	chor275.krn	*A:	maj:1:C#	maj:0:A
	chor284.krn	*C:mix	maj:0:F	maj:0:C
	chor286.krn	*b:	min:0:B	maj:0:F#
	chor288.krn	*A:mix	min:0:F#	maj:0:A
	chor291.krn	*D:	maj:1:A	maj:0:D
	chor311.krn	*F:	maj:1:C	maj:0:F
	chor314.krn	*e:	maj:0:B	maj:0:F#
	chor315.krn	*G:	min:0:E	maj:0:G
	chor333.krn	*D:	maj:0:F#	maj:0:D
	chor337.krn	*F:	maj:0:A	maj:0:F
	chor341.krn	*A:	min:0:F#	maj:0:A
	chor357.krn	*G:mix	maj:0:C	maj:0:G
	chor359.krn	*b:	maj:0:D	incmaj:0:B
	chor364.krn	*b:	maj:0:F#	maj:0:B
	chor367.krn	*b:	maj:0:D	maj:0:F#

key

humcat h://371chorales/chor001.krn | key

Estimated key: G major (r=0.9501) confidence: 52.3%

humcat h://371chorales/chor001.krn | key -a



Tonic[0]	major 0.441131	minor 0.0554652
Tonic[1]	major -0.711388	minor -0.415044
Tonic[2]	major 0.775722	minor 0.354884
Tonic[3]	major -0.301544	minor -0.42342
Tonic[4]	major -0.085096	minor 0.540753
Tonic[5]	major 0.00550523	minor -0.515126
Tonic[6]	major -0.407599	minor 0.0398076
Tonic[7]	major 0.9501	minor 0.434019
Tonic[8]	major -0.602254	minor -0.310748
Tonic[9]	major 0.158757	minor 0.224714
Tonic[10]	major -0.11878	minor -0.679797
Tonic[11]	major -0.104554	minor 0.694493

Estimated key: G major (r=0.9501) confidence: 52.3%

keycor

http://extras.humdrum.org/man/keycor

- Generalized version of the Humdrum Toolkit key program.

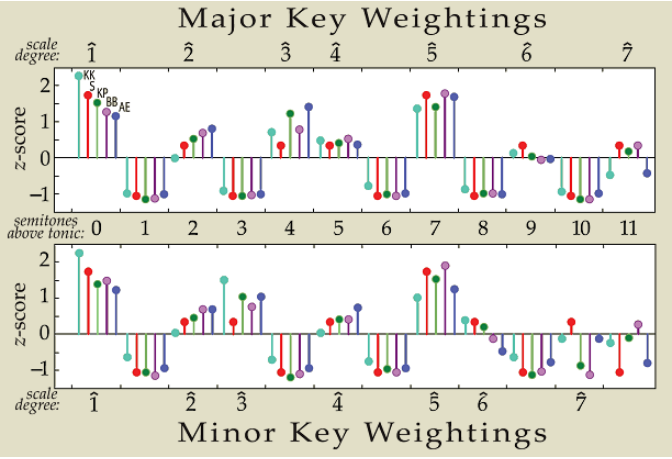
keycor h://371chorales/chor001.krn

The best key is: G Major

keycor -c h://371chorales/chor001.krn

$$R(x,y) = \frac{\sum(x_n-\bar{x})(y_n-\bar{y})}{\sqrt{\sum(x_n-\bar{x})^2\sum(y_n-\bar{y})^2}}$$

$$\text{key}_k = \arg\max_k R(x, y_k)$$

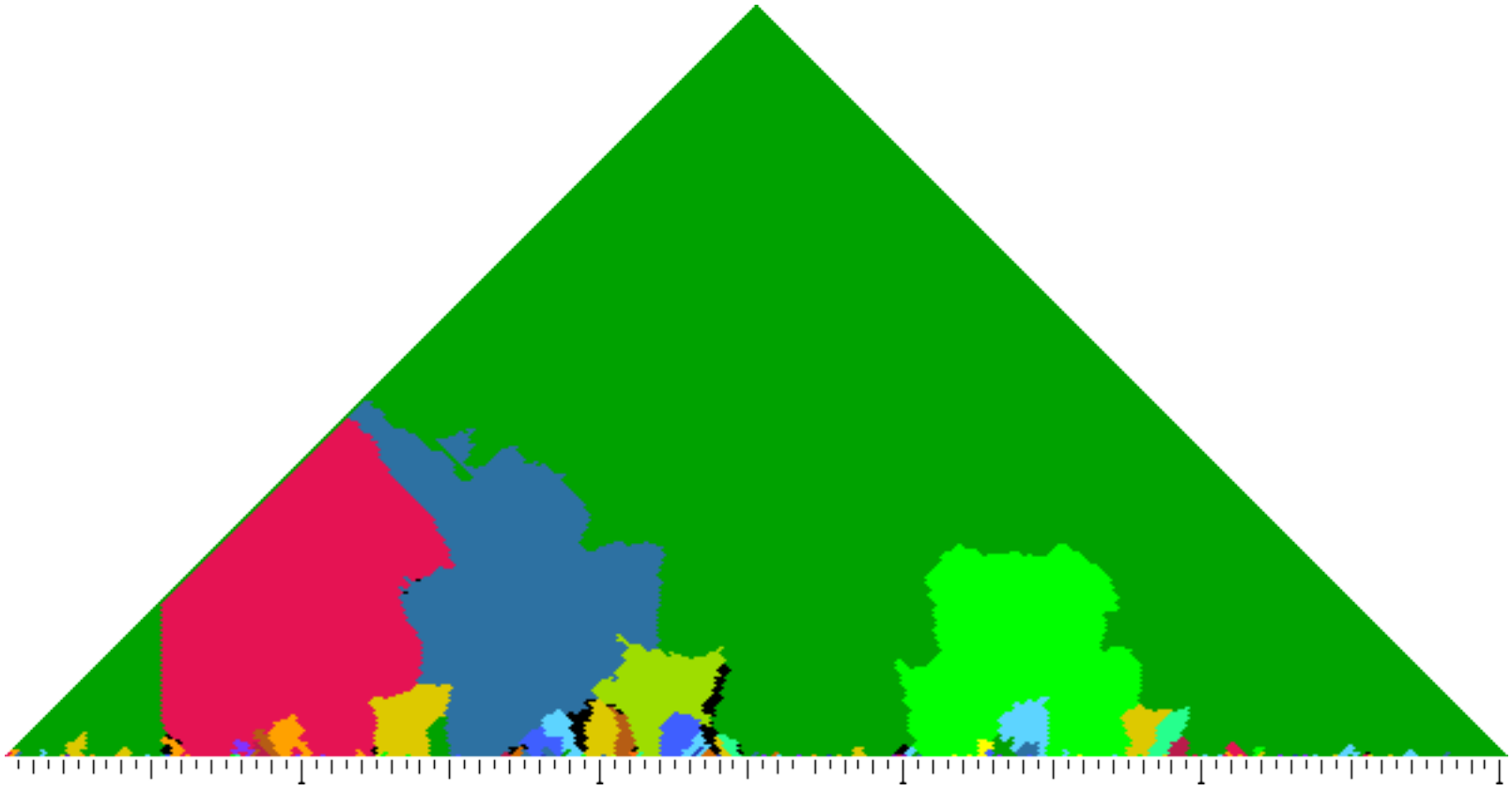


**key	**rval	**conf	**start	**mid	**end
G	0.952	82	=0	=5	=11
G	0.956	87	=1	=6	=11
G	0.973	87	=1	=6	=12
G	0.974	97	=1	=6	=12
G	0.969	90	=2	=7	=12
G	0.975	94	=2	=7	=13
G	0.971	86	=2	=7	=13
G	0.969	92	=3	=8	=13
G	0.959	92	=3	=8	=14
G	0.959	86	=3	=8	=14
G	0.969	81	=4	=9	=14
G	0.958	71	=4	=9	=15
G	0.959	70	=4	=9	=15
G	0.962	71	=5	=10	=15
G	0.963	64	=5	=10	=16
G	0.960	67	=5	=10	=16
G	0.943	64	=6	=11	=16
G	0.960	69	=6	=11	=17
G	0.954	72	=6	=11	=17
G	0.948	64	=7	=12	=17
G	0.952	66	=7	=12	=18
G	0.966	76	=7	=12	=18
G	0.976	86	=8	=13	=18
G	0.975	83	=8	=13	=19
G	0.965	87	=8	=13	=19
G	0.970	93	=9	=14	=19
G	0.975	88	=9	=14	=20
G	0.972	82	=9	=14	=20
G	0.978	80	=10	=15	=20
G	0.980	78	=10	=15	=21
G	0.972	68	=10	=15	=21
*-	*-	*-	*-	*-	*-

mkeyscape

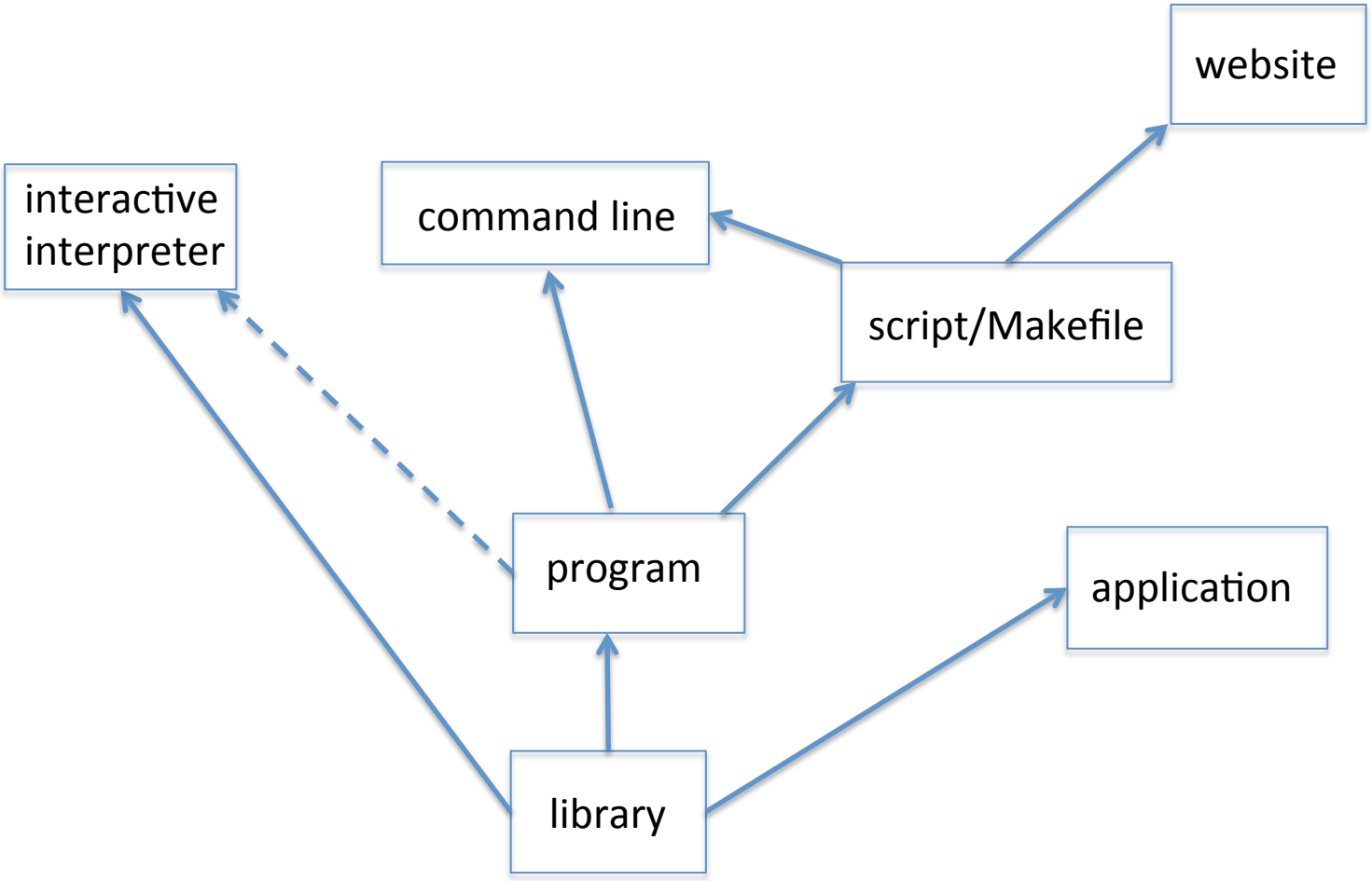
http://extras.humdrum.org/man/mkeyscape

- Structural analysis of key in a piece of music



* Beethoven's 5th symphony in C minor, first movement

Humdrum Interfacing



C++ harmony analysis skeleton

git clone https://github.com/craigsapp/humextras
cd humextras
make library

Then place the following code into humextras/src-programs/midinotes.cpp
and then type "make midinotes", then type "bin/midinotes h://371chorales/chor001.krn"

```
**kern  **kern  **kern  **kern
*Ibass  *Itenor *Ialto  *Isoprn
*k[f#]  *k[f#]  *k[f#]  *k[f#]
*G:     *G:     *G:     *G:
*M3/4   *M3/4   *M3/4   *M3/4
4GG     4B      4d      4g
=1      =1      =1      =1
4G      4B      4d      2g
4E      8cL     4e      .
.       8BJ     .       .
4F#     4A      4d      4dd
=2      =2      =2      =2
4G      4G      2d      4.b
4D      4F#     .       .
.       .       .       8a
4E      4G      4B      4g
=3      =3      =3      =3
4C      8cL     8eL     4.g
.       8BJ     8d      .
8BBL    4c      8e      .
```

```
43 59 62 67
55 59 62 67
52 60 64 67
52 59 64 67
54 57 62 74
55 55 62 71
50 54 62 71
50 54 62 69
52 55 59 67
48 60 64 67
48 59 62 67
47 60 64 67
```

midinotes.cpp (1)

```
// This program takes multiple input files or standard input and outputs a
// list of MIDI pitches sounding at a every time (line) in the input score(s).

#include "humdrum.h"

void processSegment      (HumdrumFile& infile);
void processLine         (HumdrumFile& infile, int line);
void addFieldMidiNotes   (Array<int>& notelist, HumdrumFile& infile, int line,
                          int field);

int main(int argc, char** argv) {
   Options options;
   options.process(argc, argv);
   HumdrumFileSet infiles;
   int i;
   int incount = options.getArgCount();
   if (incount < 1) {
      infiles.read(cin);
   } else {
      for (i=0; i<incount; i++) {
         infiles.readAppend(options.getArg(i+1));
      }
   }

   for (i=0; i<infiles.getCount(); i++) {
      processSegment(infiles[i]);
   }

   return 0;
}
```

midinotes.cpp (2)

```
// processSegment -- handle data extraction from one Humdrum file segment
//    (such as a movement, or individual work from a collection).
void processSegment(HumdrumFile& infile) {
   for (int i=0; i<infile.getNumLines(); i++) {
      if (!infile[i].isData()) {
         continue;
      }
      processLine(infile, i);
   }
}

// processLine --  Print notes for one line of data.
void processLine(HumdrumFile& infile, int line) {
   Array<int> notelist;
   notelist.setSize(1000);
   notelist.setSize(0);
   for (int j=0; j<infile[line].getFieldCount(); j++) {
      if (infile[line].isExInterp(j, "**kern")) {
         addFieldMidiNotes(notelist, infile, line, j);
      }
   }
   for (int i=0; i<notelist.getSize(); i++) {
      cout << notelist[i];
      if (i < notelist.getSize()-1) {
         cout << ' ';
      }
   }
   if (notelist.getSize() > 0) {
      cout << '\n';
   }
}
```

midinotes.cpp (3)

```
// addFieldMidiNotes -- Print one or more notes in a Humdrum **kern token.
//     Don't do anything if there is a rest.

void addFieldMidiNotes(Array<int>& notelist, HumdrumFile& infile, int line,
      int field) {
   int k;
   int midinote;
   int tline  = line;
   int tfield = field;
   char buffer[1024] = {0};

   if (strcmp(infile[line][field], ".") == 0) {
      // resolve data represented by null token
      tline  = infile[line].getDotLine(field);
      tfield = infile[line].getDotSpine(field);
   }

   int tcount = infile[tline].getTokenCount(tfield);
   for (k=0; k<tcount; k++) {
      infile[tline].getToken(buffer, tfield, k);
      if (strchr(buffer, 'r') != NULL) {
         // ignore rests
         continue;
      }
      midinote = Convert::kernToMidiNoteNumber(buffer);
      notelist.append(midinote);
   }
}
```