Journal of Mathematics and Music
Vol. 00, No. 00, January 2008, 1–16

RESEARCH ARTICLE

Functional Harmony Annotation Standard and Expert Groundtruth Database of Annotated Classical Music

Hitomi Kaneko[a] and Shigeki Sagayama[b]

[a] *Toho Gakuen School of Music*; [b] *The University of Tokyo*

(*v0.3 released October 2011*)

Functional harmony annotation database

Keywords: functional harmony; database;

MCS/CCS/AMS Classification/CR Category numbers: F1.1; F4.3

1. Introduction

Tonal harmony has played a central role in the Western and Western-influenced music for at least four centuries and nowadays the harmony theory is well established. Yet, it is still rarely used in automatic music processing, analysis and composition of the rapidly developing Music Information Retrieval (MIR) field. Most of the work has been done on the audio chord and key analysis problem, where some reference data has been provided by Harte [1] and several models have been proposed to deal with this problem: Hidden Markov Models [] and Bayesian []. There has also been some development in the automatic harmonization, using a constraint-based approach [3] and using Dynamic Bayesian Networks [], ... However, there is very little work in applying harmony theory to practical MIR tasks. Anglade *et al.* used chord transcriptions in their genre classification system [2]. Chemillier proposed a DJ-ing system that would match the harmony of two songsbeing mixed by utilizing formal grammars [4].

The main reason for the rarity of the usage of tonal harmony theory in the MIR world is the lack of reference data that could be used to train the parameters of the models. The only available digital harmony data source to date is the Harte' groundtruth set of

ISSN: 1745-9737 print/ISSN 1745-9745 online

DOI: 10.1080/1745973YYxxxxxxxx
http://www.informaworld.com

chord annotations for 180 The Beatles songs features on their original studio albums [1]. It is used in practically all chord recognition work, including the chord estimation task in the MIREX competition []. Furthermore, there is still no standardization in storing chord information and different researchers either invent their own ad-hoc standards or adopt the format used by Harte, usually with modifications that fit a particular task at hand. In the Harte notation, chord labels consist of a pitch class of the root, a chord type or an explicit list of member notes, relative to the root, and a pitch class of the note in the bass position. This format, although easy to use, lacks two features essential to full tonal description of music: the key of the piece with modulations and tonicizations, and the functions of the chords. This format is also focused on audio annotation, so it lacks mechanisms to express the rhythmical structure of the music.

This paper describes our work in developing a harmony annotation standard that covers virtually all aspects of harmonic annotation: chord definitions, tonal center movements, as well as the rhythmical information. We also discuss the content of the dataset that we have released, containing annotations to all classical pieces from the widely accepted RWC database made by Goto *et al.* im [5].

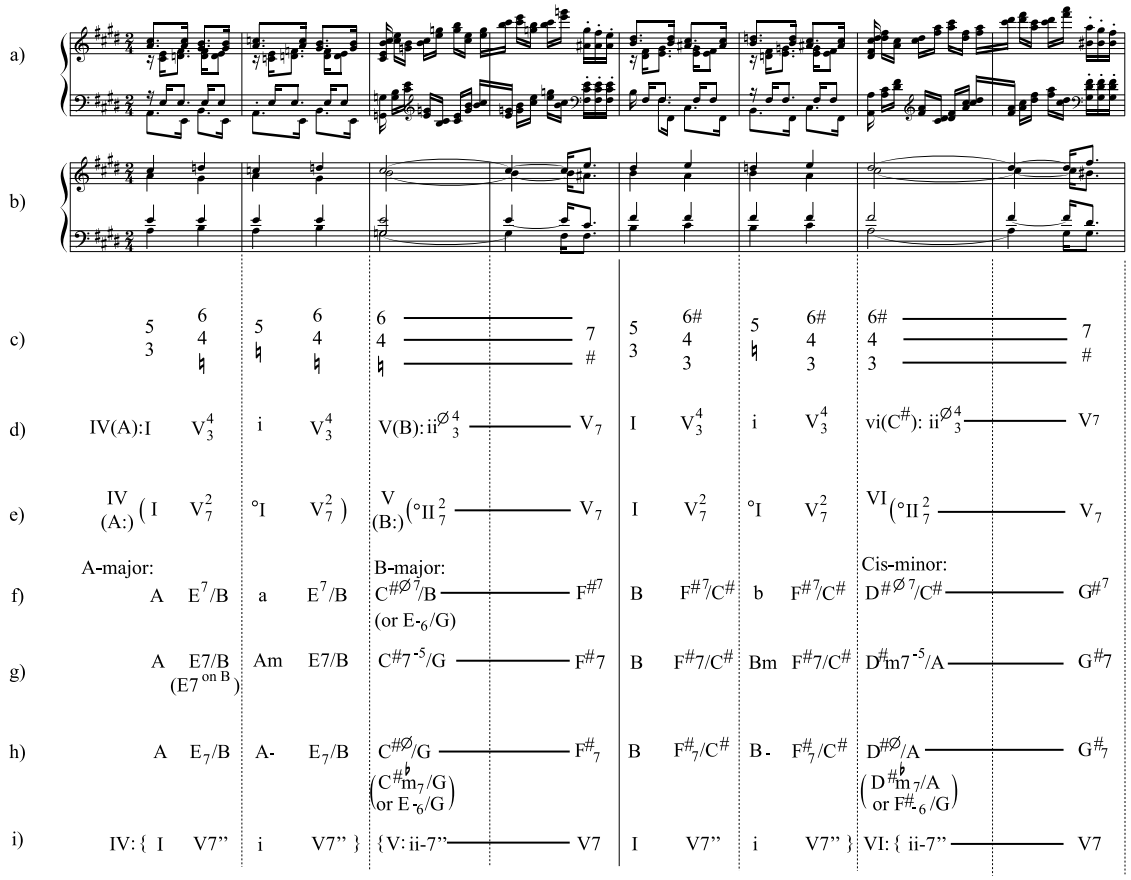
2. KSN harmony annotation standard

A harmony annotation format should be comprehensive in terms of the harmonic information it can express, but at the same time easy to use by both musicians and engineers, as well as easily parsable by machines. In computer musical notation, the ABC format [] has been gaining much popularity exactly due to its text-based simplicity, but also flexibility. As a result of joint effort between the musicologists from the Toho Gakuen School of Music and engineers from the University of Tokyo, we have developed equally powerful and intuitive text-based harmony annotation format called KSN.

2.1. File structure

A KSN file is a text file that contains harmonic annotation for a single piece of music. To give the reader a preview of the format, Listing **??** contains the full annotation for Chopin's Nocturne No. 2.

```
@K=-E @M=12/8
 11q z | I !V9’’’/I I I7’’’ | {ii: 2V7 !V9/i i} | V7 vi:V7’ vi V:!V9’ | V7 I |
 I !V9’’’/I I I7’’’ | {ii: 2V7 !V9/i i} | V7 vi:V7’ vi V:!V9’ | V7 I |
 {V: I V’} | IV iv 2I | {V: V:!V9’ V:V7’ V7 vi |
 3ii 3V7 I} {-II: V7’’’ I’} ii:V7’’ V:V7 V7 |
 I !V9’’’/I I I7’’’ | {ii: 2V7 !V9/i i} | V7 vi:V7’ vi V:!V9’ | V7 I |
 {V: I V’} | IV iv 2I | {V: V:!V9’ V:V7’ V7 vi |
```



(a) Score
(b) Harmony
(c) Figured bass notation
(d) Classical roman numeral notation
(e) Japanese Shimaoka's notation [**?**]
(f)
(g)
(h) KSN notation
(i) Harte notation(?)

Figure 1. Different harmony notation formats for Chopin's Nocturne Op. 10, No. 3, bars 30–37

```
3ii 3V7 I} {-II: V7’’’ I’} ii:V7’’ V:V7 V7 |
I !V9’’’/I I I7’’’ | {ii: V7 !V9/i i} | V7 vi:V7’ vi V:!V9’ | V7 I |
iv’’ I | iv’’ I | 2V7’’/I I V:V9+’ | V7 I |
iv I | 2iv I V:V7’ | V3!7 vi:V9’ vi V:V7’ | V9 V’ | I | I ||
```

Pitch naming convention West-European pitch naming convention is adopted in the standard. Therefore, e.g. C-major scale contains pitches named (C, D, E, F, G, A, **B**), as opposed to (C, D, E, F, G, A, **H**) used in the Central-European notation.

Comments Comments begin with a percent sign % and end with a line break.

```
@K=C              % this is a comment
I | IV | V | I || % here's another comment
```

Harmony data The harmony data is essentially a sequence of: directives, chords, bar lines, modulation indicators and repetition control marks. Like in the ABC notation, bar boundaries are marked with pipe signs | and musical phrase boundaries are indicated with double pipes ||.

```
@K=C              % music in the key of C-major
I | IV | V | I || % a phrase ending with an authentic cadence
V | V | I         % further three bars
```

All the above mentioned elements must be separated from other elements by at least one white character. All additional white characters are ignored.

2.2. Directives

All directives start with the *at* sign @. Currently defined directives are listed in Table 1.

There can be more than one directive specified in a single line, separated by white characters, they can also be mixed with the harmony data in the same line. A directive may appear anywhere in the file and applies only to the harmony data that stands after it. This will happen e.g. in situations when the meter or the key changes throughout the piece.

2.3. Note value

Note values are specified according to the current meter. The unit might be a beat, but it might also be a division of a beat. To calculate the note value in beats, the whole measure must be taken into account.

```
@M=4/4       % Note values in B (beats):
2I IV V |    %  2B (half note), 1B (quarter note), 1B
@M=12/8      %
```

	Function	**Examples**
`@K`	Specifies the key. A single letter (A, B, C, D, E, F, G) is used to determine the pitch class of the tonic (letter notation). Uppercase letters stand for major scales and lowercase letters for minor ones. Flats are specified with a minus sign − and the sharps with a plus sign `+`, placed in front of the letter.	`@K=+C % C♯-major` `@K=-d % D♭-minor`
`@M`	Specifies the meter (time signature). The first numeral defines the number of beats per measure, while the second one the note value that constitutes a single beat. They are separated by a slash sign `/`.	`@M=4/4` `@M=12/8`
`@S`	*Segno*. Marks the beginning of the repetition.	
`@C`	*Coda*. Marks the end of the repetition.	
`@F`	*Fine*. Marks the ending of the piece after the second repetition.	
`@DCAF`	*Da capo al fine*. Directive to repeat from the beginning until the end or until fine `@F`, if present.	
`@DCAC`	*Da capo al coda*. Directive to repeat from the beginning until coda `@C`.	
`@DSAF`	*Da segno al fine*. Directive to repeat from the segno `@S` until the end or until fine `@F`, if present.	
`@DSAC`	*Da segno al coda*. Directive to repeat from the segno `@S` until the coda `@C`.	

Table 1. List of currently defined directives.

```
2V7 !V9 I |  %  6B (dotted half note),
             %  3B (dotted quarter note), 3B
@M=2/4       %
5/4IV 3/4V | %  5/4B (five sixteenth notes),
             %  3/4B (three sixteenth notes)
```

The number of beats for a chord can be calculated with the following formula:

$$B_i = N \cdot L_i / \sum_k^K L_k, \tag{1}$$

where L_i is the note value specified for i-th symbol in the current measure, N is the number of beats per measure and K is the number of symbols in the current measure.

2.4. Chords

A chord definition consists of eight parts, some of which are optional. They are listed and described in Table 2.

There are three special symbols that can be used instead of the root specifier, used for specifying lack of harmony (a rest or an auftakt) or a repetition of the previous chord. None of them allows for any modificators, inversion marks or pedal notes. They are listed in Table 3.

Capital letters denote major chords, while lowercase letters minor chords. All other chord types are specified by modifying the note members with tone modificators.

Extended chords Extended chords are given by specifying the interval of the highest member note.

```
V   |  % major dominant chord
V7  |  % seventh dominant chord
V9  |  % ninth dominant chord
V11 |  % eleventh dominant chord
V13    % thirteenth dominant chord
```

All note members of the specified chord extension are present, unless specified otherwise: for example, `V13` will contain: the root, the 3^{rd}, the 5^{th}, the 7^{th}, the 9^{th}, the 11^{th} and the 13^{th}.

Explicit member notes Notes that belong to a chord may be specified explicitly using the square brackets operator `[ ]`, which groups them into a single chord. They can be given either with Latin letters (absolute pitch class), or Roman or Arabic numerals (relative pitch class). They are separated by spaces.

Just like with the key directive, flats are specified with a minus sign − and the sharps with a plus sign +, placed in front of the letter. Apostrophes can be used to specify notes from octaves higher that than of the root.

```
@K=D
[D +F A] |  % equivalent to I
[I III V] | % the same chord specified in relative terms
[I +F 5] |  % absolute and relative terms can be mixed
[V +C E'']  % E'' is two octaves higher than E
```

Explicit note members are interpreted as a non-chord with added notes:

Element	**Description**	**Examples**	
Note value (optional)	An arabic numeral indicating note value relative to the current meter. The unit is not one beat, but depends on other note values in the current measure. If no note value is specified, a unit length is assumed.	`3`	Chord lasts for 3 unit lengths.
Tonicization (optional)	Short-term (only for the duration of the current chord) modulation.	`V:`	Chord from the dominant key.
Root modificators (optional)	See Modificators.	`+`	Root is raised by a semitone.
Root specifier or member note list	Roman numeral indicating scale degree relative to the current scale or an absolute chord name (in letter notation) or a list of member notes enclosed in square brackets.	V	Dominant chord.
		`[C E]`	Notes C and E.
Modificators (optional)	Series of marks that indicate raising, lowering, deletion or addition of tones to or from the chord. Tone in question is specified with an arabic numeral indicating number of scale steps, i.e. the generic interval from the root of the chord.	`1!5+7`	Root is missing, fifth is raised by a semitone and a seventh is added.
Inversion (optional)	A series of apostrophes. Their number indicates the inversion degree.	`'''`	Third inversion.
Added notes (optional)	A series of added notes, each preceded by an ampersand.	`&2`	Added second.
		`&C`	Added C note.
Pedal note (optional)	A pedal point, i.e. single note in pedal position added to the chord, preceded by a slash.	`/I`	Added tonic in pedal position.

Table 2. Structure of a chord definition, in order of their usage.

```
[C E G]=q&[C E G]
```

Symbol	Meaning
`q`	No chord. It can be used to pad measures in case of an upbeat (anacrusis, Auftakt) or when no chord is being played (drum solo).
`z`	Rest (no notes played).
`_`	Chord repetition mark (underscore). The previous chord declaration is repeated.

Table 3. Special chord markings.

Letters	Chord intervals	Examples	
capital	root (+0), major third (+4) and perfect fifth (+7)	`@K=C` `I`	C, E, G notes.
lowercase	root (+0), major third (+3) and perfect fifth (+7)	`@K=+D` `v`	A♯, C♯, E♯ notes.

Table 4. Two basic chord types.

Symbols		Meaning
letter notation	A, B, C, D, E, F, G	Absolute pitch class. Capital letters must be used.
arabic numerals	1, 2, 3, 4, 5, 6, 7	Pitch class relative to the chord root. The numeral indicates a generic interval above the root (1 = first, 2 = second, etc.).
roman numerals	I, II, III, IV, V, VI, VII	Pitch class relative to the tonic. The numeral indicates scale degree of the note (I = tonic, II = supertonic, etc.). Capital letter must be used.

Table 5. Three symbol sets used to implicitly specify member notes of a chord.

Redundand chord defitions A single chord can be given in several equivalent forms interlaced with the equal sign `=`. This feature is mainly for the convenience of the human reader.

Modificator	**Meaning**	**Examples**	
`+`	Raising by 1 semitone	`3+`	raised third
`++`	Raising by a whole tone (2 semitones)	`++F`	F𝄪
`-`	Lowering by 1 semitone	`1-`	lowered root
`--`	Lowering by a whole tone (2 semitones)	`--C`	C𝄫
`!`	Deletion	`5!`	missing fifth

Table 6. Tone modificators.

```
@K=C
V7=[G B D’ F’] | IV’’=[C F A]
```

Altered chords Each member note can be modified with one of the following modificators:

The raising and lowering operators are generally placed before the operand with the exception of arabic numerals, which precede the operator.

```
@K=C
V3!7=[D F G] |
!V7=vii-=[VII II’ IV’]=[B D’ F’] |
V!3!9=[V IV’ VI’]=[G F’ A’]
```

When modifying the root note, the modificator can be placed directly before the chord name. When modifying the fifth, the modificator can be placed directly after the chord name.

```
!V |  % root is missing, shorthand for V1!
V+ |  % fifth is raised, shorthand for V5+
```

Modulations and tonicizations A tonicization is indicated by specifying a temporary tonic center followed by a colon mark `:`. The relative notes in the chord that immediately follows the tonicization command will be regarded as relative to the temporary tonic center. The tonicization does not carry over the redundancy mark `=`. The new tonic center can be extended to include many chords by using the curly brackets operator { }, effectively marking modulations.

```
% Bars 1-3 of Chopin’s Nocturne No. 2
@K=-E @M=12/8
I !V9’’’/I I I7’’’ | {ii: 2V7 !V9/i i} | V7 vi:V7’ vi V:!V9’
```

```
% The second bar modulates to the supertonic and the third
% bar has two tonicizations: to the relative key and to the
% dominant
```

Tonicizations and borrowed chords

Added notes Individual notes (added tones) can be added to a chord with the ampersand operator `&` and they do not have to be enclosed in the square brackets. They can be given with either: latin letters (A, B, C, D, E, F, G), to specify the absolute pitches, arabic numerals (1, 2, 3, 4, 5, 6, 7), to specify pitches relative to the chord root, or with roman numerals (I, II, III, IV, V, VI, VII), to specify pitches relative to the tonic.

```
@K=C
I3!&2&4=[C D F G] | vi&[V]=vi&[G]
```

Pedal notes If an added note is at the pedal position, the slash operator `/` can be used. This can be used to mark e.g. pedal point. Because only a single note can be added to the chord in this manner, the square brackets are not used.

```
@K=C
V/I=[C G B D']
V3!7/I=[C D F G]
```

A pedal point can be added to several chords at the same time using the grouping operator { } and the addition operator `&`. In this case, the pedal note can be preceded by the number of time units it lasts and it needs to be surrounded by square brackets.

```
@K=C @M=2/4
[8V]&{V7 I V vi | iii IV I V |}
```

Passing chords Passing chords (both diatonic and chromatic) are market with parentheses around them. For example:

```
% The first 4 bars of Brahms' The Hungarian Dance No.5
@K=+f @M=2/4
i (i'') | i (i'') | !V9'''/i (!V9''') | i (i'') |
```

2.5. Repetitions and jumps

The simplest way to specify repeats is to use the repetition operators: | :, : |, || : and : ||. These operators are used in place of the bar lines |, so only entire measures can

Repetition operator	**Meaning**
| : . . . : |	Repetition of entire measures.
|| : . . . : ||	The same as | : . . . : |, but used in place of phrase boundary marks ||.
: || :	Equivalent of : |||| :.
|| : . . . |[1 . . . : |[2	Alternative repetition endings.

Table 7. Repetition operators.

be repeated in this manner. To denote repetitions of measure fragments, a parenthesis versions of these operators are used: `(:` and `:)`. Note that that the opening repetition mark may be skipped and in that case it is assumed to be placed at the beginning of the harmony stream. If a closing mark appears in the same place as an opening mark for another repetition, they can collapse to form a : || : mark. Alternative endings are marked using |[1 and :|[2 marks.

```
 I | IV ||: V |[1 IV :|[2 I ||
% This is equivalent to:
 I | IV | V | IV | V | I ||
```

Additionally, repetition directives can be used to specify repeats and they take precedence over the repetition operators. For list of repetition directives, see Table 1.

3. Harmony annotation database

3.1. Database content

3.2. Data analysis

Rhythmic structure Fig. 2 provides us with an important observation: a chord will typically last for a single beat, sometimes for half a beat or two or three beats, occasionally for a quarter of a beat, one-half beat or four or five beats, but other lengths are virtually non-existent. This is very important for modeling chord sequences using Dynamic Bayesian models, such as the very popular Hidden Markov Model. It shows that modeling state duration explicitly (and tempo in case of real-life signals) can lead to significant improvement in the chord prediction accuracy.

The database was largely dominated by, unsurpringly, the simple meters of 2/2, 3/4, 4/4 and 2/4, and the compound duple 6/8, as shown in Fig. 3.

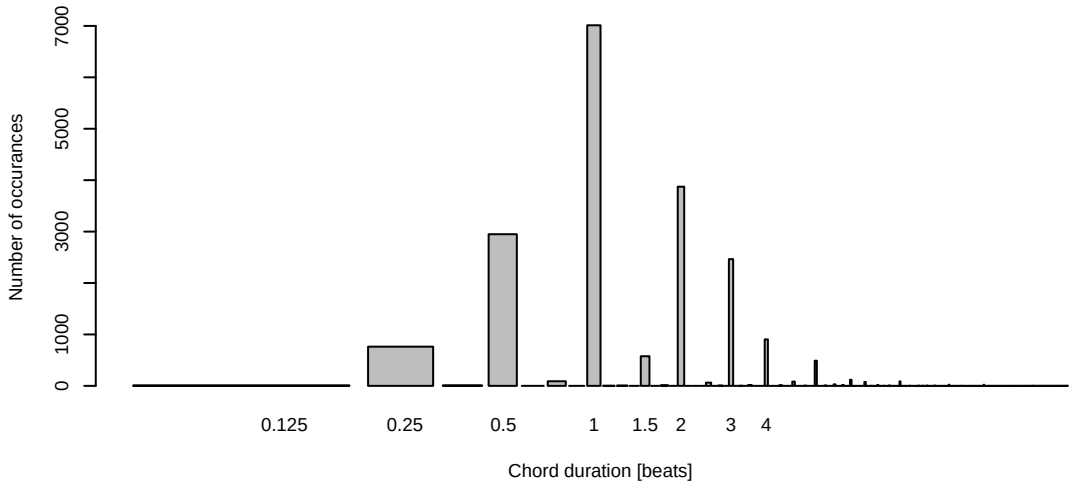


Figure 2. Distribution of chord durations in the dataset. The horizontal scale is logarithmic.

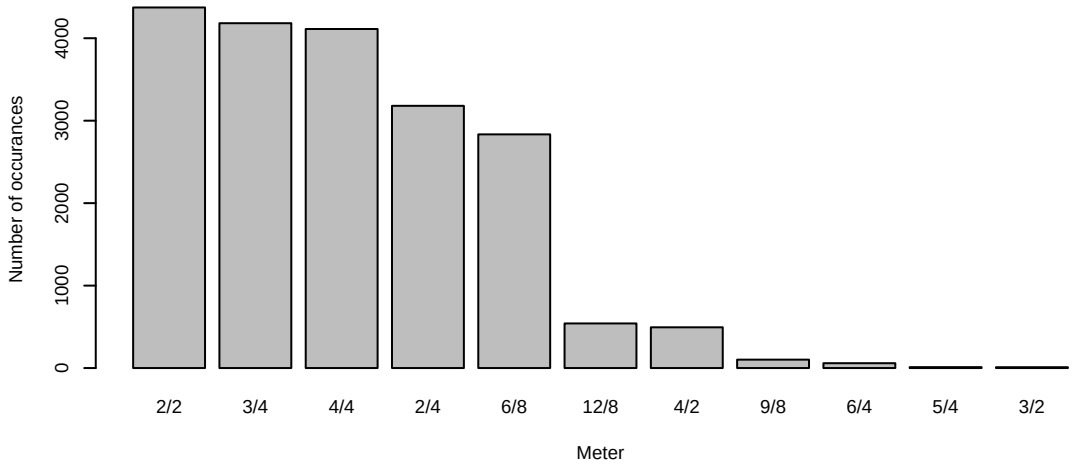


Figure 3. Meter distribution in the dataset.

Chords ...

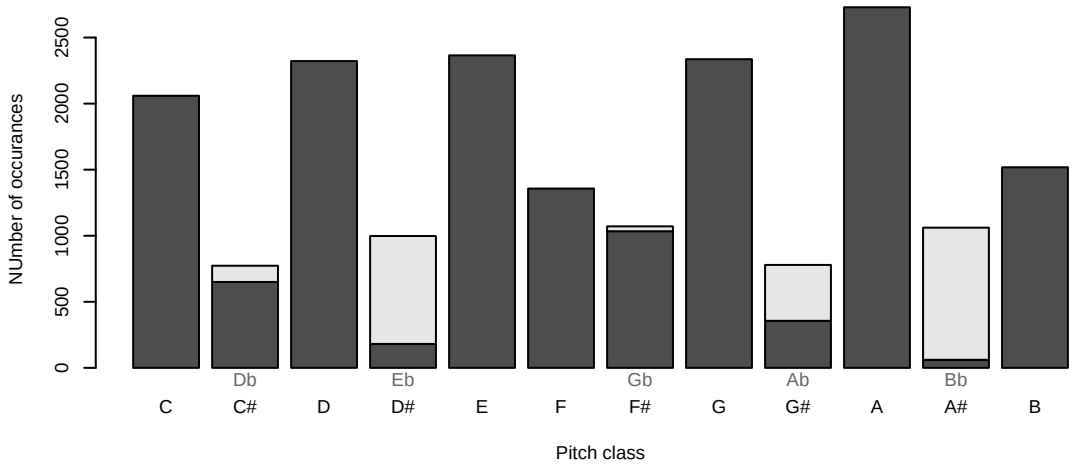


Figure 4. Distribution of chord roots in the dataset. The dark and light gray mark enharmonic spellings of the same pitch classes.

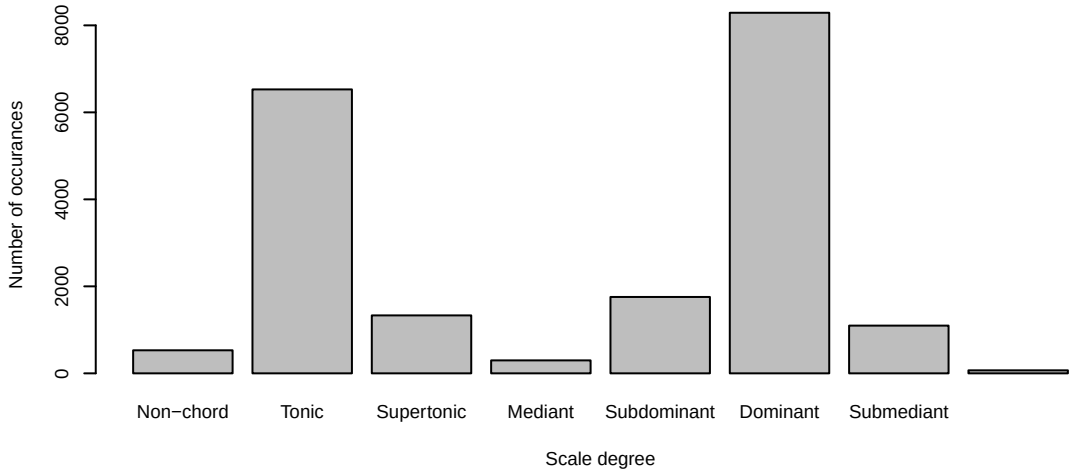


Figure 5. Distribution of scale degrees in the dataset.

Scales Figs. 7 and 8 show the distribution of major and minor scales found in the database. The distributions are similar, but mutually symmetrical around the scale that contains no accidentals.

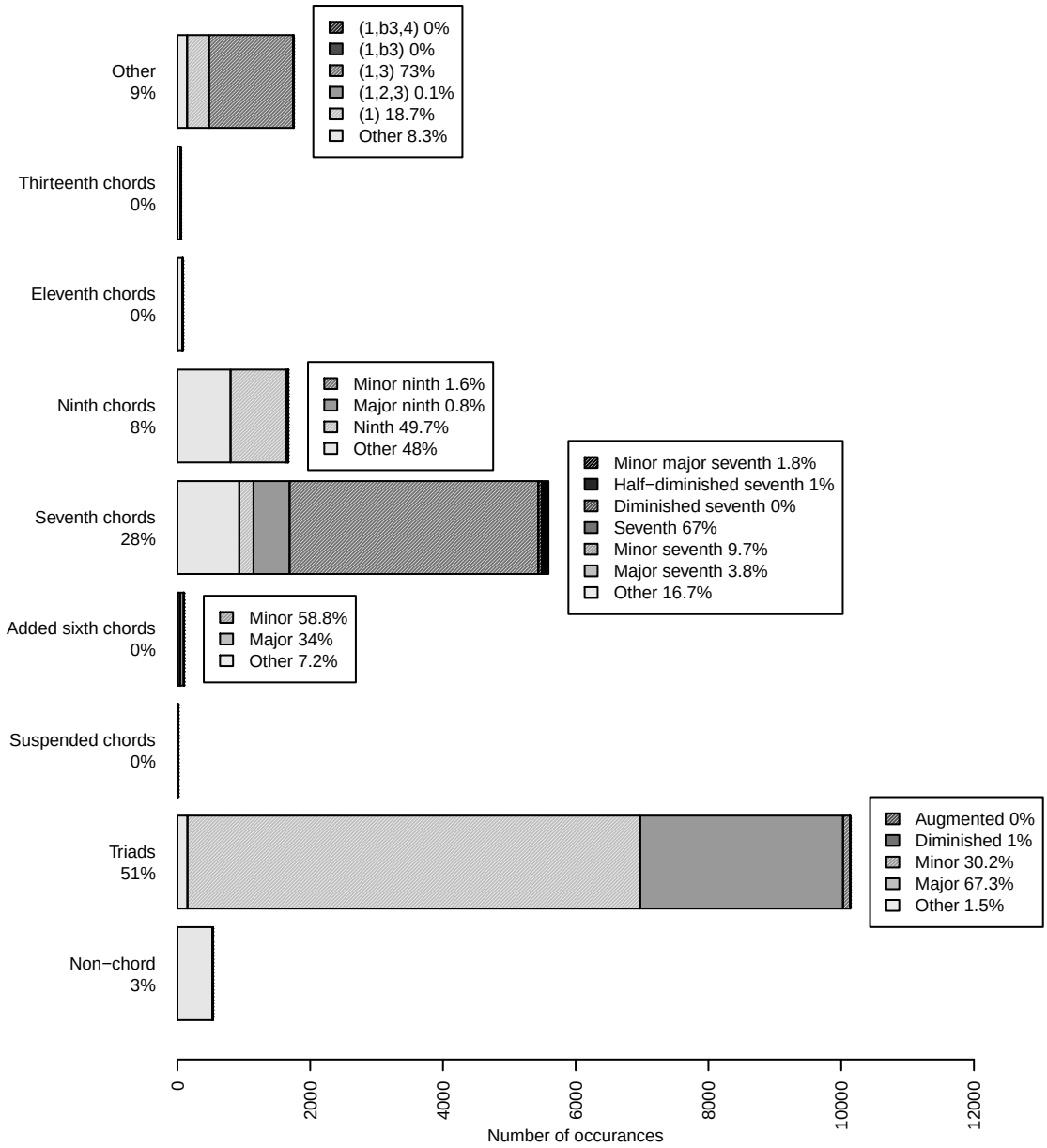


Figure 6.

Modulations ...

Chord progressions ...

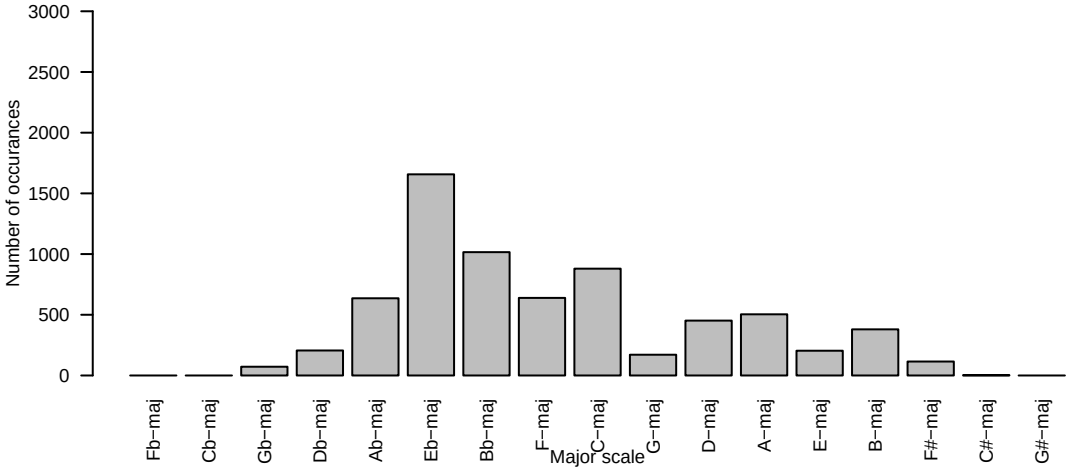


Figure 7. Distribution of the major scales in the dataset, sorted by the number of accidentals in the key signature: from 8 flats (left-most bar) to 8 sharps (right-most bar).

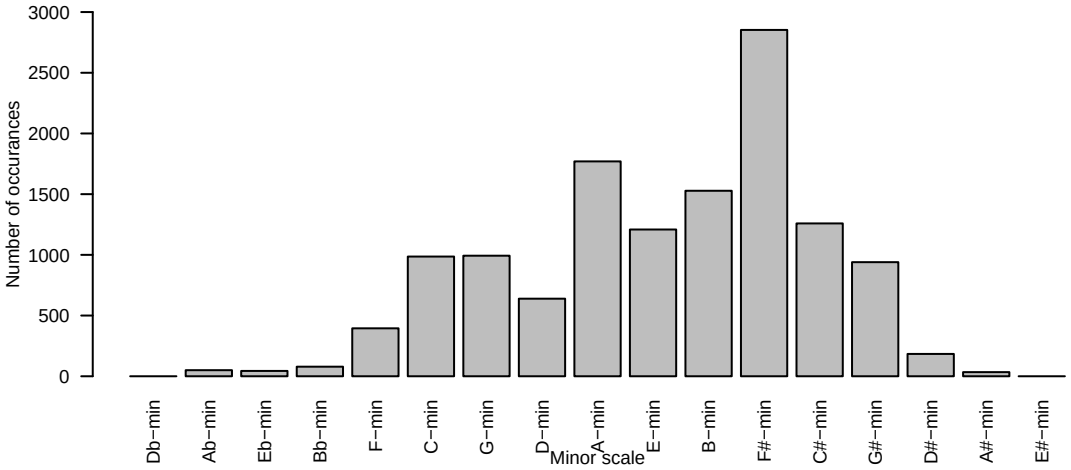


Figure 8. Distribution of the minor scales in the dataset, sorted by the number of accidentals in the key signature: from 8 flats (left-most bar) to 8 sharps (right-most bar).

References

[1] C. Harte, M. Sandler, S. Abdallah and E. Gómez, *Symbolic representation of musical chords: A proposed syntax for text annotations*, Proc. ISMIR 2005, pp. 66–71. 1, 2

[2] A. Anglade, R. Ramirez and S. Dixon, *Genre Classification Using Harmony Rules Induced from Automatic Chord Transcriptions*, Proc. ISMIR 2009, pp. ??–??. 1

[3] R. Ramirez and J. Peralta, *A constraint-based melody harmonizer*, ECAI Workshop on Constraints and Artistic Applications, 1998. 1

[4] M. Chemillier, *Improvising jazz chord sequences by means of formal grammars*, Relation, vol. 10, nr. 1.3, 2008, pp. 2022. 1

[5] M. Goto, H. Hashiguchi, T. Nishimura anr R. Oka, *RWC music database: Popular, classical, and jazz music databases*, Proc. ISMIR 2002, vol. 2, pp. 287–288.
2

Appendix A. Example annotation

As an example, let us look at the KSN labels for the file RWC-C24A and the corresponding score.

```
@K=G @M=3/4
% bars 1-16
 I | I’ | IV! | I!’ | V3!7’’ | I! | V! I!’ I! | V3!7 |
 I’ | I | IV! | I’ | 2V3!7’’ (!V’) | 2I! I!’ | ii!’ 2V | I |
% bars 17-32
 I! | V’ | 2vi! vi!7 | {V: V! | V | IV!’ I! !V’ | 2I V! } | V7 |
 I’ | IV | !I’ ii! I! | V | V | IV!’ I! !V’ | I I!’ V! | I ||
```

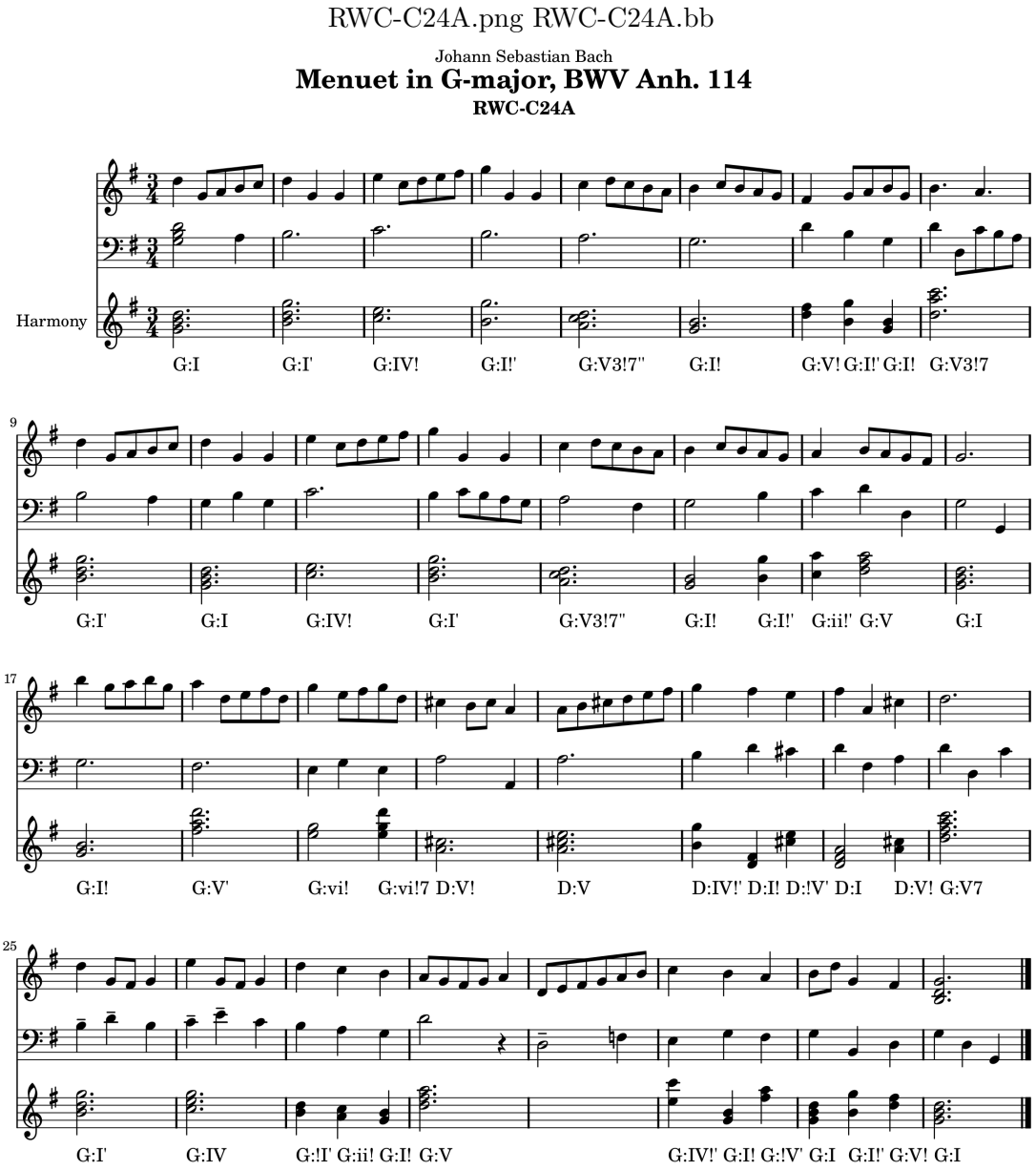


Figure A1. Score for RWC-C24A annotated with KSN-style harmony labels.