Characterisation of Harmony with Inductive Logic Programming

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Real Book RDF dataset available on: **http://chordtranscriptions.net**

Beatles RDF dataset and full sets of harmony rules available upon request

1 Introduction

We present an approach for the automatic characterisation of song sets making use of
- a human-readable **logic-based representation of musical events** which, contrary to most statistical approaches, allows to represent temporal relations and to take into account any event (even rare ones);
- **logical inference**: Inductive Logic Programming (ILP).

For this study we are interested in the **automatic extraction of harmony patterns**.

We present here the methodology and knowledge representation we adopted along with a subset of the 12,450 harmony rules obtained with our framework on a pop and a jazz dataset.

2 Methodology

Database of symbolic examples

Two manually annotated collections:
- the Beatles Studio albums (180 songs, 14,132 chords) [2]
- the Real Book jazz standards (244 songs, 24,409 chords)

We use RDF transcriptions of these collections based on the Chord Ontology (part of the Music Ontology [7]).

For each chord we have access to its **root note**, **bass note**, **component intervals**, **start time and end time**, and the **global key of the song** (for the Beatles' songs only).

Symbolic Features Extraction of harmonic events

Symbolic features computing:
- the degree using the key (for the Beatles only)
- root intervals and bass intervals between consecutive chords
- chord category for each chord (Dominant, Major, minor, augmented diminished, suspended, neutral)

Relational description of the musical events

Prolog description of the harmony of a song:
- **Positive examples**: chord sequences of length four (`chord_seq/4`)
- **Background knowledge**:
  - declaration of a unique identifier for each chord (`chord1,chord2...`)
  - description of each chord (`has_root/2`, `has_degree/2`, etc.)
  - declaration of functions that can be used by the system to build the rules (`category_seq/8`, `rootInterval_seq/8`, etc.)
- **Negative example**: `chord_seq(`**`chord2,chord1`**`,chord3,chord4)`

Inference system Aleph - based on Inverse Entailment

ILP technique: Inverse Entailment

❶ **Selection**: Select an uncovered example
❷ **Saturation**: Construct the most specific clause that entails the example selected (bottom clause)
❸ **Reduction**: Find a clause more general than the bottom clause and that maximises the coverage function (kept as hypothesis)
❹ **Cover removal**: remove the examples covered by this hypothesis
Return to ❶

Logical description of harmonic concepts

Example of rule extracted by the framework for the Real Book dataset:

```
[Rule 42][Pos cover=0.80%]:
chord_seq(A,B,C,D) :- category_seq(A,B,C,D,maj,min,min,dom),
rootInterval_seq(A,B,C,D,[maj,6th],[perf,4th],[perf,4th]).
```

represented in the following tables by:

maj —maj 6th→ min —perf 4th→ min —perf 4th→ dom

3 Experiments and Results

By far the rule with the highest coverage: 4 consecutive major chords

Possibly: instances of the same cyclic pattern maj-maj-maj-min

3 chord cyclic pattern, very common in the early compositions of the Beatles: I - IV - V - I...

	Rule	Coverage over all the Beatles songs	Coverage over the Beatles tonal songs
1.	maj → maj → maj → maj	4752 (35%)	3951 (39%)
2.	maj → maj → maj → min	632 (4.65%)	431 (4.27%)
3.	min → maj → maj → maj	628 (4.62%)	448 (4.44%)
4.	perf 4th → perf 5th → perf 4th	586 (4.31%)	-
5.	unison → unison → unison	584 (4.30%)	-
6.	maj → min → maj → maj	522 (3.84%)	384 (3.80%)
7.	maj → maj → min → maj	494 (3.63%)	363 (3.60%)
8.	perf 5th → perf 4th → perf 5th	463 (3.41%)	346 (3.43%)
9.	maj → maj → min → min	344 (2.53%)	217 (2.15%)
10.	unison → unison → unison	336 (2.47%)	237 (2.38%)
11.	min → min → maj → maj	331 (2.44%)	216 (2.14%)
12.	maj → min → min → maj	308 (2.27%)	197 (1.95%)
13.	perf 4th → maj 2nd → perf 4th	260 (1.91%)	209 (2.07%)

Top rules over the 250 rules characterising the Beatles' chord sequences obtained running Aleph on all the chord sequences of the Beatles' songs with only one negative example (cf. methodology)

"back and forth" pattern between I and IV, also identified by Mauch et al. in their statistical study [3]

	Rule	Coverage over all the Beatles songs	Coverage over the Beatles tonal songs
1.	maj —perf 4th→ maj —perf 5th→ maj —perf 4th→ maj	3.13%	3.79%
	I maj → IV maj → I maj → IV maj	-	2.47%
	V maj → I maj → V maj → I maj	-	1.00%
2.	maj —perf 5th→ maj —perf 4th→ maj —perf 5th→ maj	2.94%	3.61%
	IV maj → I maj → IV maj → I maj	-	2.43%
	I maj → V maj → I maj → V maj	-	0.84%
3.	maj —perf 4th→ maj —maj 2nd→ maj —perf 4th→ maj	1.38%	1.75%
	I maj → IV maj → V maj → I maj	-	1.59%
4.	maj —maj 2nd→ maj —perf 4th→ maj —perf 4th→ maj	1.21%	1.47%
	IV maj → V maj → I maj → IV maj	-	1.15%
5.	maj —perf 5th→ maj —min 7th→ maj —perf 5th→ maj	1.04%	1.28%
	I maj → V maj → IV maj → I maj	-	0.69%
	IV maj → I maj → bVII maj → IV maj	-	0.52%
6.	maj —perf 4th→ maj —perf 4th→ maj —maj 2nd→ maj	0.93%	1.11%
	V maj → I maj → IV maj → V maj	-	1.03%
7.	maj —perf 4th→ maj —perf 4th→ maj —perf 5th→ maj	0.91%	1.09%
	V maj → I maj → IV maj → I maj	-	0.83%

First line of each cell: Top rules characterising the Beatles' chord sequences obtained when we constrain Aleph to derive rules about intervals between chord roots (capture degree information) and chord categories
Second and third lines: associated degree and chord category rules

Inverse Entailment guarantees that the set of rules obtained with Aleph is a sufficient and non-redundant description of the data ➡ useful for classification

Possible explanation: the famous jazz pattern ii-V-I-IV

Certainly I-VI-II-V (turnaround)

	Rule	Coverage over all the Real Book
1.	perf 4th → perf 4th → perf 4th	1861 (7.86%)
2.	min → dom → min → dom	969 (4.09%)
3.	min → dom → maj → min	727 (3.07%)
4.	dom → min → dom → min	726 (3.07%)
5.	min → min → min → min	708 (2.99%)
6.	dom → dom → dom → dom	674 (2.85%)
7.	perf 4th → perf 4th → unison	615 (2.60%)
8.	maj 6th → perf 4th → perf 4th	611 (2.58%)
9.	perf 4th → perf 5th → perf 4th	608 (2.57%)
10.	dom → min → dom → maj	594 (2.51%)
11.	dom → maj → min → dom	586 (2.47%)
12.	perf 4th → unison → perf 4th	579 (2.45%)
13.	maj 6th → perf 4th → perf 4th	547 (2.31%)
14.	maj → min → dom → maj	478 (2.02%)

Top rules over the 596 rules characterising the Real Book chord sequences (using one negative example only)

First time such an ILP approach is applied on such a scale:
- We dealt with unified corpora of songs commonly accepted as representative of a composer/band/genre ➡ datasets musicologists would typically study
- Aleph computed all the rules in less than a minute on a regular desktop ➡ this can save time to musicologists

4 Conclusion

- A first analysis show that **very common pop and jazz patterns** emerge from the rules derived by our framework
- We hope that an in-dept musicological analysis of the full set of rules would reveal less common and more specific patterns
- **This technique could be used by musicologists** to automatically characterise the harmony of large sets of songs in few seconds

Future work:
- Test whether such rules can efficiently be used for **classification** and **clustering** purposes
- Try to characterise **other musical phenomena** (rhythm, melody, structure)
- Adapt our ILP framework to **audio data**