N-GRAM CHORD PROFILES FOR COMPOSER STYLE REPRESENTATION

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ABSTRACT

This paper studies the problem of using weighted N-grams of chord sequences to construct the profile of a composer. The N-gram profile of a chord sequence is the collection of all N-grams appearing in a sequence where each N-gram is given a weight proportional to its beat count. The N-gram profile of a collection of chord sequences is the simple average of the N-gram profile of all the chord sequences in the collection.

Similarity of two composers is measured by the cosine of their respective profiles, which has a value in the range $[0, 1]$. Using the cosine-based similarity, a group of composers is clustered into a hierarchy, which appears to be explicable. Also, the composition style can be identified using N-gram signatures.

1 INTRODUCTION

The chord progression is an important component in music. Musicians and listeners speak of novel and influential chord progressions, typified in the First Act Prelude of "Tristan und Isolde" by Richard Wagner, in "Because" by The Beatles, and in "Giant Steps" by John Coltrane. Among many genres of music the role of chord progressions is the most significant in Jazz, where performances are improvisational and thus performers often choose to play tunes with interesting chord progressions. While many jazz compositions are constructed based on well-known chord progressions, such as 12-bar blues progressions and "I Got Rhythm" by George Gershwin, there are composers, such as Thelonius Monk and Wayne Shorter, whose chord progressions are thought of as unique. The importance of chord progressions in Jazz raises the questions of whether they can be effectively used for music retrieval and whether they can be used to characterize composers, which we will address in this paper.

An approach to the problem of comparing two chord progressions is sequence alignment, as often used in melody-based music retrieval (see, e.g., [2, 6, 11, 12]). The basis for the sequence-alignment approach is a theory that explains transformation of a chord progression to another (see, e.g., [8, 10]). Such a generative theory offers musical understanding of how two progressions are similar, but has a limitation that not all pairs of progressions are necessarily comparable. Also, for comparing multiple progressions with each other, generative-theory-based comparisons may be too computation-intensive. This consideration suggests the use of N-grams—the patterns consisting of N-consecutive chords that appear in a chord sequence. The use of N-grams is very popular in natural language understanding (see, e.g., [5]). In music information retrieval, N-grams have been shown effective for melodic contour analysis [3,4,9]. Also, the recent work of Mauch et al. [7] use 4-grams to examine the chord sequences of The Beatles.

While the chord sequences are an important subject in musicology, we believe that they can be incorporated into a tune retrieval system where the tunes are indexed with metadata and chord sequence. In such a system, a user provides a chord sequence (either typed or copy-pasted from a sequence on screen) as input and the system retrieves tunes that contain a part with either exactly the same as (with the possibility of allowing transposition of the key) or similar to the input sequence, where the input chord progression is specified using an unambiguous notation system (such as the one in [1]).

Highly prominent in the Jazz harmony are the 6th, 7th and major 7th notes and the tensions (the 9th, the 11th, and the 13th notes). The former signify the functions that chords possess while the latter add color to triads. Chord progression analysis in terms of triads is likely to enable fundamental understanding of the chord structure, but perhaps deeper understanding can be obtained by examining these non-triad notes. Our work extends [7] by considering functional and additional notes such as the 6th, 7th, and tensions, by creating a profile out of N-gram data, and then by assigning the similarity between two profiles.

1.1 Organization of the paper

The rest of the paper is organized as follows: Section 2 describes the method for obtaining an N-gram profile of chord sequences; Section 3 describes the experiments; and Section 4 describes conclusions and discusses future work.

2 THE METHOD

2.1 N-Grams

2.1.1 N-Grams

Let U denote the universe of chords. For integers $N \geq 1$, an N-gram is an ordered N-tuple $(u_1, \ldots, u_N)$ such that $u_1, \ldots, u_N \in U$. We say that an N-gram $(u_1, \ldots, u_N)$ such that $u_1, \ldots, u_N \in U$ is *proper* if for all i, $1 \leq i \leq N-1$, $u_i \neq u_{i+1}$.

2.1.2 Chord simplification

The universe, U, of chord names is vast. There are twelve possible choices for the root (without distinguishing between sharps and flats); four for the 3rd (Minor, Major, Sus4, Omitted 3rd); four for the 5th ($^\flat 5, ^\natural 5, ^\sharp 5$, Omitted 5th); four for the 6th/7th (the 6th, Minor 7th, Major 7th, no 6th or 7th); four for the 9th ($^\flat 9, ^\natural 9, ^\sharp 9$, no 9th); three for the 11th ($^\natural 11, ^\sharp 11$, no 11th); and three for the 13th ($^\flat 13, ^\natural 13, ^\sharp 13$, no 13th). These make the total number of choices more than 27,000, and so, the total number of possible N-grams becomes 761 millions for $N = 2$ and 21 trillions for $N = 3$. In addition, chords can be augmented with a use of a bass note different than the root of the chord, which further increases the number of N-grams. While the space of N-grams can be enormous, the N-grams are sparse. In fact, the N-grams appearing in a progression with M chord changes is only $M - N + 1$. Even though the distributions of chords are often very skewed (towards certain keys and towards chords without tension notes), the vastness may make it unlikely for the N-gram profile of a chord progression with highly enriched chords to intersect with the N-gram profile of another chord progression. This problem can be overcome by simplifying chords.

The concept of simplification corresponds well with that of stemming in document processing, which is the process of removing modifiers of words thereby making words generated from the same root with difference modifiers treated as identical words. We divide of the process of simplifying a chord into two parts: (1) turning a fractional chord (a chord with an attached bass note, such as AMI7 on B) into a non-fractional chord and (2) simplifying the tensions and the 6th/7th. We consider three options for the first part:

- $(B0)$ simply removing the bass note (for example, AMI7 on B is turned into AMI7),
- $(B1)$ reorganizing the notes so that the bass note becomes the root (for example, AMI7 on B is turned into B7sus4 ($^\sharp 5, ^\flat 9$)), and
- $(B2)$ incorporate the bass note as a tension (for example, AMI7 on B is turned into AMI9).

We consider three options for the second part:

- $(T0)$ removing entirely the tensions and the 6th/7th note,
- $(T1)$ removing entirely the tensions but keeping the 6th/7th note, and
- $(T2)$ replacing the whole tension notes with a single bit of information as to whether the chord has any tension and keeping the 6th/7th note.

We also consider the possibility of keeping all the tensions intact and keeping the 6th/7th note. We will denote this option (not a form of simplification though) by T_3. Then our simplification method is expressed as a pair (Bi, Tj) such that $0 \leq i \leq 2$ and $0 \leq j \leq 3$. The most aggressive simplifications are $(Bi, T0), 0 \leq i \leq 3$. Each of these simplifications reduces a chord to a triad and thus reduces the number of possibilities for a chord name to 192. For a progression Π and a simplification method τ, we will use $\tau(\Pi)$ to denote the progression Π after applying τ.

We will be interested only in proper N-grams. So, given an input chord progression, after simplification we collapse all the consecutive entries whose chord names are identical to each other into one entry whose duration is the total of the durations of the subsequence. After this modification every block of N-consecutive entries corresponds to an N-gram, so we call such a chord progression a *proper* chord progression. Note that simplification applied to a proper N-gram may produce a non-proper N-gram.

2.1.3 N-gram transposition

Also, since popular songs are transposed to different keys, in our analysis of N-grams we are only interested in how chords are changed after the first chord. We will thus transpose each N-gram locally, in such a way that each N-gram starts with a code having A as the root. For example, from a five-chord sequence [FMI7, B$^\flat$7, E$^\flat$MA7, CMI7, B7], we obtain three 3-grams, FMI7 – B$^\flat$7 – E$^\flat$MA7, B$^\flat$7 – E$^\flat$MA7 – CMI7, and E$^\flat$MA7 – CMI7 – B7, which are then transposed respectively to AMI7 – D7 – GMA7 A7 – DMA7 – BMI, and AMA7 – F$^\sharp$MI7 – F7. We call this process *A-transpose*.

2.1.4 Chord sequences and Weight of N-grams

We assume that each chord progression is a series of chord names each accompanied by a positive rational, which represents the number of beats during which its chord is to be played. In other words, a progression Π is a sequence $[(u_1, d_1), \ldots, (u_m, d_m)]$ such that for all i, $1 \leq i \leq m$, u_i is a chord name (belonging to the universe U of chord names) and d_i is a nonnegative rational.

We next assign a weight to each N-gram produced from a proper chord progression, for the purpose of considering the contribution that the chord progression makes to the tune.

For example, we consider that the contribution of a 4-chord pattern DMI7 - G7 - EMI7 - A7 when one beat is allocated to each chord is different from that when four beats are allocated to each. We approximate the contribution of an N-chord pattern by the total number of beats assigned to the chords. For an N-gram $(a_i, a_{i+1}, \ldots, a_{i+N-1})$ of a proper chord progression $\Pi = [(a_1, \ell_1), \ldots, (a_N, \ell_N)]$, its contribution is thus $\ell_i + \cdots + \ell_{i+N-1}$.

2.1.5 N-gram profile of chord sequences

For a chord progression Π, a simplification method τ, and a positive integer N, the N-gram profile of the progression Π with respect to τ, denoted $\Theta[\tau, N](\Pi)$, is the set of all pairs (w, c), where w is a proper N-gram appearing in Π and c is the total contribution of w (since w may appear at more than one place in Π) divided by the total contribution of all N-grams appearing in Π. By assuming that the weight is 0 for each N-gram not appearing in Π, $\Theta[\tau, N](\Pi)$ can be viewed as the set

$$\{(w, c) \mid w \text{ is an A-transposed proper } N\text{-gram appearing in } \tau(\Pi) \text{ after applying simplification } \tau \text{ and } c \text{ is the weight of } w \text{ in } \tau(\Pi)\}.$$

Given a collection C of chord sequences $\Pi_1, \ldots, \Pi_s$, the N-gram profile of C with respect to τ, $\Theta[\tau, N](C)$, is the average of $\Theta[\tau, N](\Pi_1), \ldots, \Theta[\tau, N](\Pi_s)$, that is, $\frac{1}{s}\sum_{j=1}^{s} \Theta[\tau, N](\Pi_j)$.

Figure 1 shows the melody and the chord progression of "Yesterdays" composed by Jerome Kern. Due to the space constraint on the drawing software, the minus sign is used for minor chords. With the $B0$-simplification, the two fractional chords at the end of the first line, DMI/C$^\sharp$ and DMI7/C, are respectively turned into DMI and DMI7. The chord progression has the following 3-grams after A-transpose: AMI–BMI7($^\flat$5)–E7 (16 beats), AMI7($^\flat$5)–D7–GMI (14 beats), A7–DMI–EMI7($^\flat$5) (8 beats), A7–DMI–DMI7 (8 beats), AMI–AMI7–F$^\sharp$7($^\flat$5) (8 beats), AMI7–F$^\sharp$7($^\flat$5)–B7 (12 beats), AMI7$^\flat$7–D7–G7($^\sharp$5) (12 beats), A7–D7($^\sharp$5)–G7 (12 beats), A7($^\sharp$5)–D7–G7 (12 beats), A7–D7–G7 (24 beats), A7–D7–GMA7 (12 beats), A7–DMA7–G$^\sharp$7($^\flat$5) (12 beats), AMA7–D$^\sharp$7($^\flat$5)–G$^\sharp$7 (12 beats).

2.2 Profile Comparison Using Cosine-based Similarity Measure

Given two profiles Π_1 and Π_2, we compute the similarity between them by the cosine of the two. More precisely, if $\Pi_1 = (u_1, \ldots, u_k)$ and $\Pi_2 = (v_1, \ldots, v_k)$, then the similarity between the two is:

$$\frac{u_1 v_1 + \cdots + u_k v_k}{\sqrt{u_1^2 + \cdots + u_k^2}\sqrt{v_1^2 + \cdots + v_k^2}}.$$

The cosine can be thought of as representing the similarity between the two because the value of cosine is 1 for two identical N-gram profiles and 0 for two N-gram profiles with no common N-gram patterns.

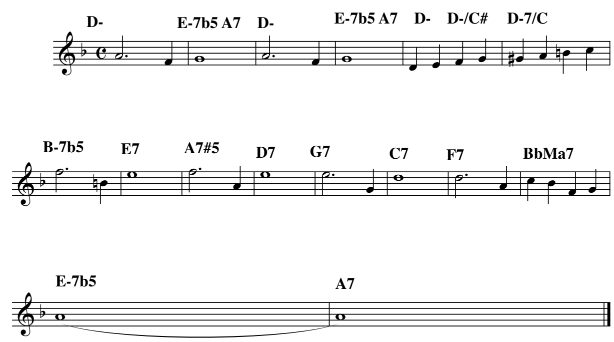

Figure 1. The melody and the chord progression of a Jerome Kern composition "Yesterdays".

3 EXPERIMENTS

3.1 Data

We collect from jazz fake books (Real Book 1, 2, and 3; New Real Book 1, 2, and 3; Jazz Limited) 218 chord progressions of the following modern jazz composers: John Coltrane (28 tunes), Chick Corea (25 tunes), Duke Ellington (25 tunes), Herbie Hancock (16 tunes), Freddie Hubbard (17 tunes), Thelonius Monk (27 tunes), Wayne Shorter (47 tunes), and Horace Silver (33 tunes). We exclude Fusion compositions of them, in particular, the Wayne Shorter compositions for the Weather Report and the later periods, the Herbie Hancock compositions for The Headhunters, and the Chick Corea compositions for The Elektric Band, fearful that addition of such tunes would make these composers too different from the rest of the composers. We also collect 63 "standard" tunes from Real Book 1. These are restricted to contain neither compositions by modern jazz musicians, nor Bossa Nova. Finally, we collect 20 compositions of The Beatles from the Hal Leonard Publishing "Anthology Volume 3". We consider these 20 compositions to be something not similar to the Jazz Fakebook tunes. An archive of the data files can be obtained at: www.cs.miami.edu/∼ogihara/chord-sequence-files.zip.

3.2 Comparison of the simplification methods

3.2.1 The choice of N and bass note simplification

To determine the value for N and and to choose the bass note simplification, we examine the cosine-based similarity between the standards and D. Ellington with respect to each of the twelve simplification methods. The similarity values are shown in Table 1. Since D. Ellington played the most prominent role in founding the modern jazz theory and the chord progressions of the Fakebook standard tunes in some sense summarize the chord sequences resulting from Jazz reharmonization, it is anticipated that the two groups are very similar, in particular, when the tension notes are excluded (namely, $T0$ simplification). So this comparison suggests that $N = 3$ or $N = 4$ will be a good choice.

The choice of the bass note simplification (the B-part) does not seem to affect much the similarity measure, while the choice for the tension note simplification (the T-part) makes a substantial difference, in particular, for the 3- and 4-gram similarity. The phenomenon that the selection on

Method		N			
T	B	1	2	3	4
$T0$	$B0$	0.990	0.950	0.818	0.579
	$B1$	0.990	0.950	0.818	0.579
	$B2$	0.990	0.950	0.818	0.576
$T1$	$B0$	0.954	0.835	0.628	0.319
	$B1$	0.953	0.836	0.630	0.320
	$B2$	0.952	0.834	0.626	0.310
$T2$	$B0$	0.950	0.798	0.504	0.197
	$B1$	0.949	0.797	0.500	0.190
	$B2$	0.947	0.796	0.497	0.187
$T3$	$B0$	0.952	0.805	0.502	0.194
	$B1$	0.951	0.804	0.500	0.189
	$B2$	0.950	0.804	0.500	0.185

Table 1. The cosine-based similarity between the standards and D. Ellington with respect to various simplification methods.

the bass note simplification doesn't affect similarity much can be explained by the fact that only a small fraction (less than 5%) of the chords appearing the data had a bass note. This observation leads us to choose $B0$ (bass note omission) for the bass note simplification, because it is the simplest operation.

3.2.2 Tension simplification

We next examine how different the similarity value is depending on the choice for the T-part in the method. It is anticipated that the more aggressive the simplification is, the higher similarity values become, and this is clearly exhibited in Table 1 that shows comparisons between the standards and the D. Ellington tunes. According to the table, there is much difference between the $T2$ and $T3$ simplifications. Since $T2$ is more aggressive than $T3$, and thus, the resulting chord notation is generally simpler with $T2$ than with $T3$, we should choose $T2$ over $T3$.

We then compare $T0$ and $T1$ using the songs by The Beatles and those by the others. The numbers are shown in Table 2. There is a substantial difference in the similarity

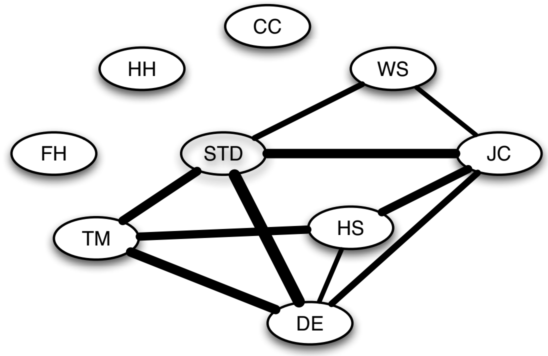

Figure 2. The similarity graph of the Jazz composers.

value between $T0$ and $T1$. Given that The Beatles is in the Pop/Rock genre and the rest are in Jazz, we feel that $T1$ is more appropriate than $T0$. Since the similarity of The Beatles to these composers seems very high for $T0$, we consider using $T1$ instead of $T0$.

Composer	1-gram		2-gram	
	$T0$	$T1$	$T0$	$T1$
CC	0.933	0.594	0.527	0.250
DE	0.993	0.521	0.715	0.239
FH	0.921	0.570	0.456	0.114
HH	0.827	0.354	0.346	0.078
HS	0.962	0.483	0.621	0.178
JC	0.983	0.562	0.790	0.241
TM	0.998	0.551	0.691	0.243
WS	0.950	0.373	0.500	0.164

Table 2. Comparison between $T0$ and $T1$.

These observations narrow our choices down to $(B0, T1)$ and $(B0, T2)$.

Table 3 shows the comparison of The Beatles, T. Monk, and H. Hancock with respect to the $(B0, T1)$-simplification and the $(B0, T3)$-simplification. We note that as N increases the similarity of the standards more quickly decays with The Beatles and Herbie Hancock than with Thelonius Monk and the decay is more dramatic with the 6th/7th kept in the chord names and further more dramatic with the tensions kept.

Figure 2 shows the cosine-based similarity of the profiles among the Jazz composers with respect to 3-grams and $(B0, T2)$-simplification. Two composers are connected if the similarity is 0.2500 or higher. The thicker the line is, the higher the similarity value is. The actual similarity values of these lines are summarized in Table 4. Since the similarity is symmetric, the upper right portion of the table is left blank and the two $<$'s appearing in the last line indicate that

	Standards Versus		
N	The Beatles	T. Monk	H. Hancock
1	0.430	0.922	0.875
2	0.163	0.716	0.390
3	0.040	0.437	0.114
4	0.017	0.199	0.038

	Standards Versus		
N	The Beatles	T. Monk	H. Hancock
1	0.414	0.886	0.829
2	0.162	0.676	0.185
3	0.040	0.378	0.051
4	0.018	0.1580	0.010

Table 3. Cosine-based comparison of N-gram profiles between the standards and each of The Beatles, T. Monk, and H. Hancock. for $N = 1, 2, 3, 4$. Top: with respect to the $(B0, T1)$-simplification. Bottom: : with respect to the $(B0, T3)$-simplification.

	STD	DE	HS
DE	0.504		
HS	0.349	0.376	
TM	0.379	0.422	0.363
JC	0.402	0.278	0.349
WS	0.267	$<$	$<$

Table 4. Composer Similarity

the similarity value is not more than 0.2500.

This graph coincides seems to reflect well the relations among the composers from the historical perspective. According to the year of the first recording session as a leader, these composers are ordered as follows: Ellington (1924), Monk (1947), Silver (1955), Coltrane (1957), Shorter (1959), Hubbard (1960), Hancock (1962), and Corea (1966). The graph connects among the first five along with the standards and disconnects the remaining three from every one else.

3.3 Artist clustering using profiles

This historical is more strongly represented in hierarchical clustering of the composers. Figures 3 and 4 show the hierarchical clusters of the composers generated using 3-grams, the former with the $(B0, T1)$-simplification and the latter with the $(B0, T2)$-simplification.

3.4 Unique N-gram signatures

We also consider the question of whether N-gram profiles can be used to identify a composition style. To study this question, for each composer we look for an N-gram w such that the frequency value of w with respect to that composer has a large positive gap from the frequency value of w with respect to any other composer. For each simplification method and for each $N = 1, 2, 3, 4$, we compute top 20 N-grams in terms of the narrowest positive gap from the value with respect to any other composer.

Table 5 shows the most distinctive 4-grams of the composers when compared against the rest. We note that the most prominent patterns in the standards in contrast with the rest are perfect-4th movements. This agrees with the observation of Mauch et al. [7] that the standard jazz tunes have frequent occurrences of perfect-4th movements. Also, the distinctive patterns of other composers contain chromatic, major 2nd, and minor 3rd movements.

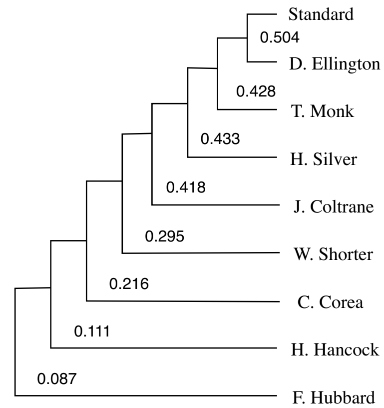

Figure 3. Hierarchical clustering of the composers with respect to the $(B0, T1)$-simplification. The Beatles is not included.

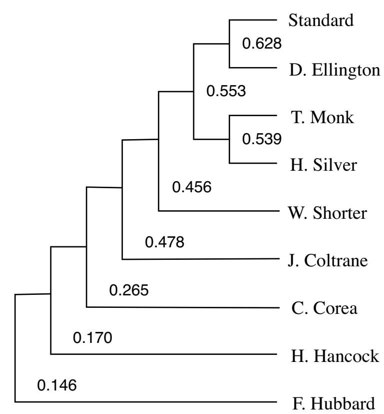

Figure 4. Hierarchical clustering of the composers with respect to the $(B0, T3)$-simplification. Again, The Beatles is not included.

Name	4-gram	Freq. Value	Max. Others
STD	AMI7–DMI7–G7–CMA7	0.891	0.304
	A7–DMI7–G7–CMA7	0.789	0.225
	AMI7–D7–GMA7–EMI7	0.815	0.300
	AMI7–D7–GMA7–CMA7	0.776	0.291
BTLS	A–E–A–E	4.396	0.345
	A–D–A–D	3.964	0.357
FH	AMI7–C7–B7–A♯MA7	6.250	0.000
	A7–G7–A7–G7	3.274	0.823
CC	AMI–DMI–AMI–F7	1.000	0.000
	AMI7–EMI–C–D	0.680	0.000
DE	Adim.–A♯MI7–D♯7–D♯MI7	0.799	0.000
	A7–DMI6–A7–DMI6	0.785	0.000
HH	AMI7–F7–F♯SUS7–AMI7	3.125	0.000
	A7–A♯SUS7–C♯MI7–A7	1.563	0.000
WS	A7–G7–A7–AMI7	1.084	0.000
	A7–F♯7–B–A♯MI7	1.042	0.000
HS	AMI–D7–AMI–G♯7	1.299	0.000
	AMI6–F7–AMI6–E7	1.299	0.000
JC	A7–G7–A7–CMI7	1.587	0.000
	A7–DMA7–F7–A♯MA7	1.449	0.210

Table 5. The most distinctive 4-grams of the composers with respect to the $(B0, T1)$-simplification. For each 4-gram, the "Freq. Value" column shows its frequency in the composer and the "Max. Others" column shows its maximum frequency in any other composer.

4 CONCLUSIONS AND FUTURE WORK

In this paper we explored the use of N-gram profiles generated from chord progressions to find a composition style. Of the twelve possible methods of chord simplification, we identified two to be the most promising. We used the chord profile to cluster artists in a hierarchy, which seems to be consistent with the composition styles from the historical perspective. It will be interesting to conduct more extensive studies to examine usefulness of chord progression profiles with more genres and more composers. The fact that the frequencies are very small for most of the N-grams raises the question of whether there is a more appropriate alternative for the distance measure that accounts for the sparseness. Another interesting direction will be to study the relation between the melody line and the chord progression and question whether the relation shows unique characteristics of composers.

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