Analysis of Improvised Jazz Melodies Using Harmonic Tags

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***Abstract*—Jazz improvisation has many similarities to spoken language, and it might be expected that large language models would be effective tools for information retrieval and generative applications applied to it. There are, however, important practical differences. The success of modeling natural language has, in part, been due to the availability of vast corpora of symbolic text. By comparison, collections of transcribed jazz are orders of magnitude smaller. For this reason, neural architectures are unlikely to be as effective for music as they have been for text without the support of additional information. For applications with limited data, various strategies have been shown to be helpful, one of which is the injection of domain knowledge. The objective of this paper is to analyze the relationship between melody and harmony as a method for extracting jazz-specific domain knowledge. To that end, we describe an automated system for identifying and tagging harmonic features of jazz melody, and apply it to a corpus of 325 transcribed, bebop-style solos with over 300,000 notes. A unique aspect of our work is that the tags are based on terminology used by jazz musicians, and this allows us to directly analyze the statistical characteristics of improvisational devices taught by educators and found in instructional books. Our analysis confirms the expressiveness of harmonic tagging, and identifies a convergence of vocabulary used across the thirteen musicians represented in our data. The results show that harmonic tags capture useful domain knowledge and should be beneficial in improving the effectiveness and accuracy of deep learning architectures applied to jazz applications.**

***Index Terms*—Music retrieval, Music generation, Feature extraction, Domain knowledge, Music, Jazz**

I. Introduction

A key characteristics of jazz is the spontaneous composition of melody, but this is a challenging skill to master. Learning jazz has parallels to how adults learn a second language [1]. After internalizing enough vocabulary and grammar, a critical level of fluency is achieved that allows the student to extemporaneously interact with others. Whether this is how the learning process works for jazz is beyond the scope of this paper, but there are hundreds of books and articles that teach the "vocabulary" of jazz, implicitly assuming this cognitive model to be effective [2]–[9]. How jazz improvisation is learned is a subject studied by musicologists [10], [11], cognitive scientists [12]–[14], sociologists [15], and researchers interested in building generative and analytical music technologies [16]–[18]. There are, however, few studies linking scientific models to instructional guides, which may be due to the historical sparsity of data. With recent availability of large corpora of transcribed solos [19], [20], an analysis of jazz educational materials becomes more tractable.

This paper makes three main contributions. The first is the introduction of a unique system of tags designed to describe the harmonic function of notes in a way that mirrors the vocabulary used by jazz educators. This has the advantage of making our results more understandable to musicians and other domain experts while specifying a rich feature set. The second is an in-depth statistical analysis of these tags as they relate to improvisational devices as presented by two well-respected jazz instructional books [4], [5]. The results show that our tagging system is comprehensive, accounting for over 95% of notes in the database, and that the relative frequencies of vocabulary types are consistent across the musicians in our corpus. The third contribution is an analysis of the books' pedagogical guidelines, confirming some, extending others, and in one case identifying a misconception.

II. Data

Three sources of data were used in this study. The first is a collection of Charlie Christian solos found in [21]. This data was manually digitized by this paper's first author. It consists of 35 solos, with 9,723 notes played over 1,844 chords. The second is the collection of solos found in the Charlie Parker Omnibook [22], digitized to XML format by [23]. It contains 50 songs, with 25,535 notes played over 4,465 chords. The last is the Filosax jazz saxophone corpus [19], consisting of 48 jazz standards individually played by five professional jazz saxophonists. Each participant played each song's standard melody (in jazz parlance, *the head*), followed by one chorus of a famous solo by Stan Getz, Tubby Hayes, Dexter Gordon, Ben Webster, Sonny Rollins, or Joe Henderson. Each participant then plays several choruses of their own improvised melodies. To avoid repetition bias, the heads and famous solos of each song are included only once (as performed by Player1). Filosax contains 240 performances with 272,789 notes played over 60,584 chords. Collectively, the three datasets contain 314,371 notes played over 68,229 chords, as improvised by thirteen different musicians.

III. Preprocessing

To facilitate the labelling of notes in a harmonically and metrically meaningful way, we perform two pre-processing

steps. The source material for our data is primarily monophonic, however, there are some examples of concurrent notes. We have suppressed the note of lower pitch value based on the general practice being that the higher pitch is usually the main melody note. In addition, we have opted to suppress grace notes because although they play an important stylistic and ornamental role in jazz, they do not contribute to the melodic context of this work. Finally, some notes have metrical positions and durations that traverse chord boundaries. A note whose onset begins over one chord and terminates over another has a harmonic function that changes at the transition. As our focus is on the interactions between harmony and melody, we split these types of notes into two parts, allowing the note to have distinct tags for each harmonic context

IV. Harmonic Tagging of Melody

Instructional books explain jazz melodic vocabulary in terms of the tonal and modal centers implied by their chord progressions. Our objective is to analyze jazz pedagogy through the proxy of performance practices, and we do this for each note by identifying its relationship to the chord it is played over and classifying it with a harmonic tag. To make our analysis relevant to jazz teachers and students, the tags are defined based on concepts commonly used by this community:

- **Chord tone**: a note belonging to the chord it is played over.
- **Anticipation note**: a note played just prior to the transition to a new chord that is not a chord tone of the current chord but is for the new one. This common device in jazz creates a sense of dissonance and tension followed by resolution [5], [24].
- **Prolongation note**: a note played or carries over past the transition to a new chord and which is a chord tone of the previous chord but not the current one. This is a device that creates tension [5] and is usually resolved by the following note being consonant with the new chord.
- **Color tone**: a non-chord tone that is a 9^{th}, 11^{th}, or 13^{th} with respect to the root of the chord. Color tones are sometimes called chord extensions. They enrich a chord's sound without altering its fundamental function.
- **Semitone approach note**: a non-chord tone directly preceding a chord tone and either a semitone above or below it. These notes create a dissonance that is usually immediately resolved by the ensuing chord tone.
- **Altered tone**: a note played over a dominant seventh chord and a ♭9, ♯9, ♭5, or ♯5 with respect to the root of the chord [3]. As dominant chords are often used to create harmonic dissonance, the altered tones reinforce and amplify this.
- **Enclosure tones**: sequence of three notes where the final one is a chord tone, the first two are each within two semitones of it, one pitched above and the other below the chord tone.

In addition to these labels, we include a tag for rests and one for the notes played over a no-chord symbol. As will be discussed in Section V, these nine tag types are fairly

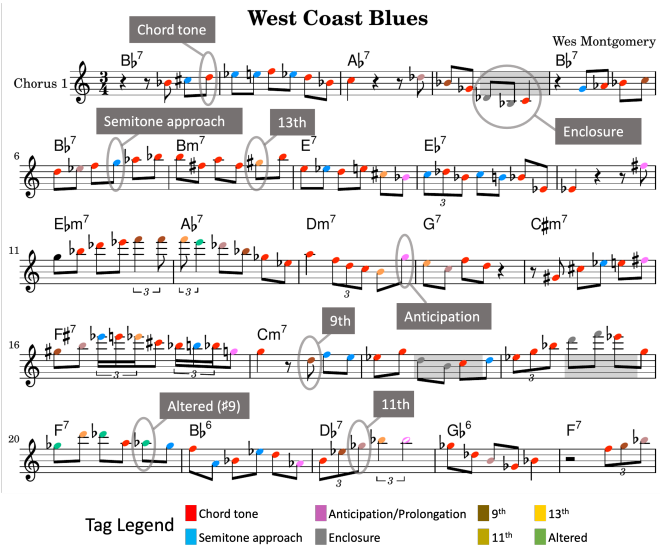

Fig. 1. Visualization of tag types for the first 15 bars of Wes Montgomery's solo over *West Coast Blues*.

comprehensive in that they account for almost all the melodic symbols in our corpus. It is important to state that some notes could be interpreted as more than one tag type, but we have adopted a precedence that is congruent with how jazz musicians think about these cases. For example, in Figure 1 bar 20, the note annotated as an altered ♯9 could also be interpreted as a semitone approach. However, as this note is played over a dominant seventh chord, it has a function that is more specific as an altered tone, which takes precedence. The complete order of precedence from highest to lowest is as follows: (1) enclosures, (2) chord tones, (3) anticipation and prolongation chord tones, (4) color tones, (5) altered tones, and (6) semitone approach notes.

A visualization tool was developed for this work using the Lilypond music engraving software package [25], and Figure 1 illustrates an annotated example. Each note's tag is encoded using a colored note head. The legend for each tag-type's color is provided on the figure. In this solo, Wes Montgomery uses all the tag-type attributes in the list except for prolongation notes. In the ensuing section, we present in-depth statistics on how these are used by a cohort of professional musicians.

V. Aggregate Statistics of Tagged Melody

Using a publicly available package that converts chord symbols to their constituent chord tones,[1] we implemented an automated system for labelling notes with the tags defined in Section IV. Table I is a summary of the tag statistics as applied to our corpus, showing tag types broken down by frequencies per source (Charlie Christian, Charlie Parker, Filosax) and for the aggregate. The table is organized by descending frequency of tag types for the aggregate corpus. Chord tones are the most common, representing a little less than half of all the melodic symbols. Semitone approach notes are next largest,

[1]https://github.com/no-chris/chord-symbol

at 6.3%, followed by the individual color tones (however, as a group, they make up 13.2%). The tags for anticipation and prolongation make up 2.7% and 1.5%, followed by the altered notes (which as a group represent 5.1%). Finally, a small number of notes (0.1%) have no harmonic function because they are played over the no-chord symbol. Our tagging scheme accounts for 96% of all notes.

Type	Charlie Christian	Charlie Parker	Filosax	All
Chord tone	46.2	44.2	48.5	48.1
Rest	13.3	11.1	15.6	15.2
Semitone approach	7.4	8.6	6.1	6.3
9^{th}	8.0	6.3	5.5	5.6
13^{th}	6.6	5.4	3.9	4.1
11^{th}	3.4	3.8	3.5	3.5
Enclosure (3 notes)	1.8	4.4	3.5	3.5
Anticipation	2.8	2.3	2.8	2.7
Prolongation	1.2	1.2	1.5	1.5
♯9	1.0	1.7	1.5	1.5
♯5	1.8	1.7	1.4	1.4
♭9	1.3	2.4	1.2	1.3
♭5	0.7	1.8	0.9	0.9
No chord	0.3	0.0	0.1	0.1
Total	95.7	94.1	96.0	95.8

TABLE I
TAG TYPES AND THEIR FREQUENCIES OF OCCURRENCE

The table highlights two important characteristics of this style of jazz. First, the rank ordering of tag types by frequency is almost identical across the three constituent corpora. At the note level, this suggests a compositional convergence across the musicians sampled by our data. Their melodic improvisations are using similar percentages of harmonic ingredients. Second, the table reveals a characteristic of bebop jazz with respect to the interplay between consonance and dissonance. Disregarding rests, the consonant notes (chord tones) represent 58% of all notes played. Dissonant notes (semitone approach, anticipation, prolongation, altered, and one out of three of the enclosure notes) make up 20%, and color tones (9^{th}s, 11^{th}s, and 13^{th}s, and one third of enclosures) constitute 17%. This observation about the interplay between consonance and dissonance seems to reflect an insight about what make the bebop style of jazz interesting.

Depending on the type of analysis, the entries in Table I can be grouped in a variety of ways. As our objective is to compare data with advice from instructional materials, we define the following classes. Chord tones are the most important, and by definition are the most harmonically consonant to the chord progression. Color tones are the second class because as a group they are extensions to and consistent with chord tones. The remaining classes are the chromatic and altered notes, which are harmonically dissonant. Recognizing some ambiguities, it will facilitate our further analysis to assemble the aggregate statistics into four functional meta-classes. We define the chord tone class for the entire corpus as the first row of the *All* column in Table I and a third of that column's enclosures (49.3%). The color tone class, consisting of 9^{th}s, 11^{th}s, 13^{th}s, and a third of the enclosures (14.4%). The tension class consists of semitone approach notes, anticipation and prolongation chord tones, and one third of enclosures (11.7%). Finally, the altered class makes up 5.1%. We place the altered tones in a class of their own because, unlike notes in the tension class, they do not have the characteristic of always being followed by a resolution note. Defined in this way, Figure 2 illustrates the meta-class elements of jazz follow a distribution with chord tones three times more frequent than color or tension tones, which in turn are three times more common than altered notes.

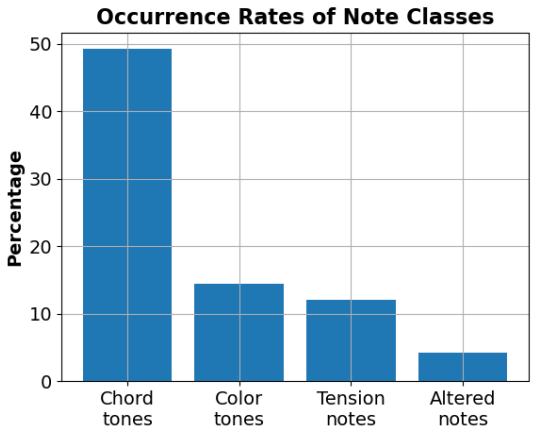

Fig. 2. Relative occurrences of note classes

VI. COMPARISONS WITH JAZZ IMPROVISATION INSTRUCTIONAL GUIDELINES

As our tagging system is based on concepts used by jazz educators, we can use the data from our corpus to analyze two well-regarded jazz improvisation instructional books. The first is Jerry Coker's *Elements of the Jazz Language* [4], and the second is Bert Ligon's *Connecting Chords with Linear Harmony* [5]. Coker's perspective on the vocabulary of improvised jazz is summed up in the book's foreword (edited for brevity):

> *I took my copy of Ken Slone's book,* 28 Modern Jazz Trumpet Solos*, and 15-20 colors of felt-tipped pens, and worked out a coded, color bracket system for marking the solos... The result was a real eye-opener!... I wasn't fully aware that the "Common Devices" list was so uniformly shared by all fifteen players whose solos were contained in the book, ranging from the likes of Fats Navarro and Dizzy Gillespie to Tom Harrell and Randy Brecker!... all players were using the devices... there was virtually nothing left unmarked in the solos, though there were only 18 devices on the list.*

The foreword of Ligon's book has a similar passage:

> *Students brought in short examples from jazz solos... We noticed... that all the examples seem[ed] to fit into three categories. They were based on... three*

basic skeletal frameworks. All of them followed the principles of linear harmony: consonant notes (usually thirds) in rhythmically significant places leading to dissonances (sevenths) which resolved to consonant notes again, usually over the bar line.

There is significant overlap between the books, but too many devices to cover comprehensively in this paper. We have selected a subset of language elements that, from our experience, are most widely used.

A. Tension Notes

As mentioned above, an important characteristic of jazz melody is the interplay between tension and resolution. Coker's and Ligon's books describe several tension devices: semitone approach notes, anticipation and prolongation notes, altered tones, and in part, enclosures. These note types and their aggregate statistics are covered by our tagging system, and as discussed in Section V, constitute roughly 20% of notes played for this genre of jazz.

B. Melodic Devices Used to Transition between Chords

The way in which the notes of a jazz melody harmonically transition from the end of one chord to the beginning of the next is a core characteristic of the genre. Coker devotes a chapter of his book to this, specifically focused on iim7-V7-IM7 major cadences. The method he describes is based on playing the ♭7 of the iim7 followed by the 3rd of the V7 at the transition between the two chords. This is characterized by a downward movement by one semitone. Similarly, there is a semitone descent at the transition from the ♭7 of the V7 to the 3rd of the tonic (IM7). This technique of small intervallic transitions between chords is known as *voice leading*, and in jazz, is often referred to as *playing the changes*. For the listener, this method clearly outlines the changes in harmony. Ligon devotes most of his book to this technique, extending it to the minor cadence, and including embellishments. Not all chord transitions, however, are from a iim7 to V7 or a V7 to IM7, and not all are from a 7th to a 3rd. We are interested in characterizing voice leading between all chord transitions.

To study this, we use the chord tone tags to compile the statistics of all chord transition intervals. As other note types, such as chromatic leading tones (or rests), are often sandwiched between chord tones, we define a transition between adjacent chords as the last chord tone of the first chord and the first chord tone of the second. However, because long rests are indicative of a phrase boundary, we exclude the transitions containing a half note rest or more.

Figure 3 illustrates an example snippet containing four chord transitions within a lead sheet segment. Reading from left to right, the first chord tone interval across a chord transition descends by four semitones, the second descends by three semitones, the third ascends by three semitones and the fourth ascends by one semitone. The third instance also illustrates a case with a semitone approach (blue note head) sandwiched between the two chord tones. The aggregate distribution of all chord-tone intervals across chord transitions

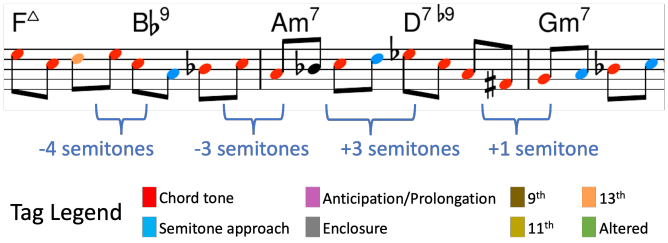

Fig. 3. Four chord transitions from a transcription of *Have You Met Miss Jones* as played by Johnny Smith. From left to right, the pitch intervals are -4, -3, $+3$, and $+1$ semitone.

is presented in Figure 4. The histogram shows that small intervallic movement is a predominant feature of our data, with 74% of the mass between four descending and four ascending semitones (constituting a major third).

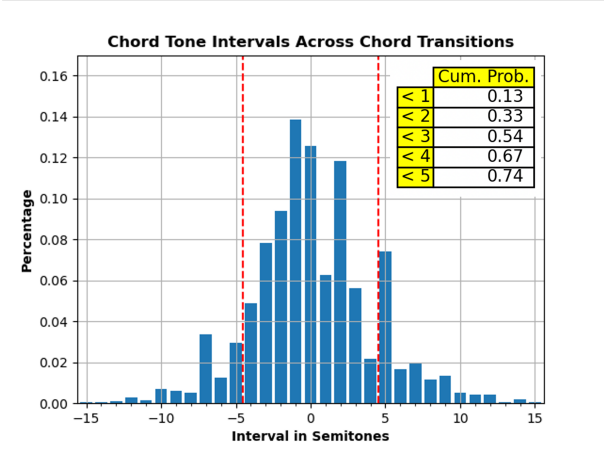

Fig. 4. Histogram of intervals between chord tones at chord transitions. Ascending intervals are positive and descending negative. The vertical dashed red lines delineate the chord-tone transitions less than or equal to four semitones. The table shows the cumulative probabilities for the melodic interval to be less than 1, 2, 3, 4, or 5 semitones.

For four-note chords consisting of a root, 3rd, 5th, and 7th, there are sixteen types of chord tone transitions, and their frequencies of occurrence in our data are compiled in Table II. The table presents the probabilities of transitions from the chord tone type of the first chord (row) to that of the second chord (column). The most common transition type, and the one treated in both Coker's and Ligon's books, is from a 7th to a 3rd, at 9.4%. The least common is from a 7th to a 7th with a value of 3.0%. That said, we observe that the probabilities of the 16 types are relatively uniform. So, although this confirms that the book discussions are useful pedagogical models for how to voice lead between chords, students need to include the other cases in their study.

C. Melodic Devices Used within Chords

The two books we studied describe a variety of melodic devices used within the harmonic scope of a single chord. We first discuss is enclosures. Figure 5 shows two examples, where

	root	3rd	5th	7th
root	7.5%	6.4%	7.4%	4.5%
3rd	6.1%	5.2%	5.8%	5.0%
5th	8.1%	7.3%	6.3%	4.4%
7th	3.9%	9.4%	4.8%	3.0%

TABLE II

TRANSITION STATISTICS FOR A CHORD TONE TYPE OF THE FIRST CHORD (ROW) TO THE TYPE OF THE SECOND CHORD (COLUMN). A TRANSITION FROM A 7^{TH} TO A 3^{RD} IS THE MOST COMMON TYPE, BUT AT 9.4%, IS ONLY SLIGHTLY MORE IMPORTANT THAN OTHER TRANSITION TYPES.

a light gray background is used to highlight the three notes as a unit. The first two notes of an enclosure are commonly a semitone approach note and a scale tone, and because of this, the device has built in tension and resolution. Counting enclosures as three notes, their frequency of occurrence per constituent corpus is given in Table I. As the use of enclosures is a stylistic and compositional choice, it may be a characteristic that could be used to identify an artist, or potentially a time period. For example, the table shows that Charlie Parker used them more than twice as often as Charlie Christian.

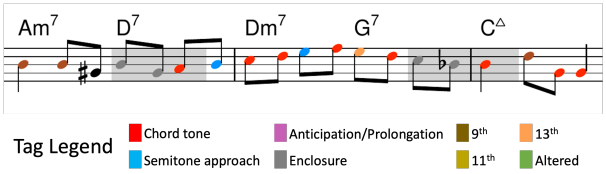

Fig. 5. Example of two enclosures from *Just Friends* as performed by Player 3 in the Filosax dataset. The first, on the left, resolves to the note A, the 5th of the chord D7. The two preceding notes are a B and a G, both whole tones from the A. The second resolves on a B, the 7th of the CM7, and preceded by the C and B♭, each a semitone from the B.

D. Bebop Scales

Bebop scales have eight notes consisting of a typical seven-note scale (major, melodic minor, harmonic minor, and their modes) plus an additional chromatic note. Many sources claim that the term was introduced by David Baker in his book *How to Play Bebop* [26]. He states "the added chromatic tones make the scales come out right", explaining a bit later that, in part, when using it "all the chord tones are on down beats". This observation, that the Bebop scale places chord tones on down beats, has been widely reprised in instructional materials for jazz, and is often presented as an important method for learning how to improvise. Coker devotes two chapters to it.

As most of our corpus is in the Bebop style of jazz, we can use it to evaluate Baker's premise about the placement of chord tones on down beats. For each measure, we compiled the frequency of chord-tone onsets for each of the eight eighth-note beat locations (all of the music in our corpus is $\frac{4}{4}$ time). Figure 6 shows the results. The down beats are numbered 1, 2, 3, and 4, and the up beats are labeled with the "&" symbol. The height of each bar is the ratio of the number of chord tones to all notes having an onset at that beat. The horizontal gray dashed line delineates the 50% level. As annotated on the graph, the onsets of 10% of the notes in our corpus do not fall

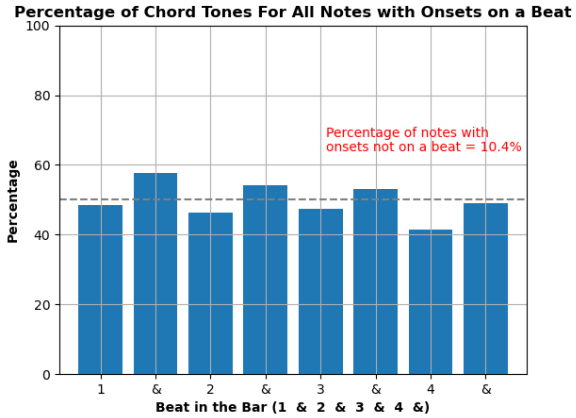

Fig. 6. The conditional probability of a note being a chord tone at each metrical position. The gray dashed line is the 50% level. Chord tones are used almost uniformly across all beats, not just the strong ones, and conditionally, are a bit more common on the off beats.

on any of the eight positions due to metrical structures such as tuplets and 16th notes).

From Baker's book, a student might surmise that chord tones should be played predominately on down beats, and avoided on up beats. The figure, however, demonstrates that accomplished jazz musicians play chord tones on all beats, and moreover, chord tones are conditionally more likely on up beats than down beats. This may be due, in part to syncopation, as illustrated in Figure 7, showing an example of chord tones used on off beats to create this effect. That chord tones are used on all the beats is an important insight for both students of jazz, the development of machine generated jazz music, and for tasks related to music information retrieval for this genre.

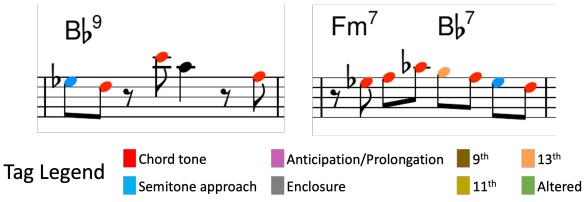

Fig. 7. Syncopation puts chord tones on up beats, as shown by the red note heads in this figure. The left is an extract from the song *There Will Never Be Another You*, with chord tone onsets on beats 2, 4, and 8; and the right is an extract from *For Regulars Only*, with chord tones on beats 2, 3, 4, 6, and 8. Both are due to Filosax player 3.

VII. DISCUSSION AND CONCLUSIONS

We have introduced a system of harmonic tags for the analysis of melody and have used it to analyze the structure of jazz improvisation. Some past work has introduced labels for short sequences of notes [20], however, to our knowledge, this paper is the first to introduce tags focused on the terminology of jazz pedagogy found in instructional books. Our corpus contains transcribed solos from a range of famous artists, including Charlie Christian, Charlie Parker, Stan Getz, Tubby Hayes,

Dexter Gordon, Ben Webster, Sonny Rollins, Joe Henderson, and a mix of contemporary, working jazz musicians. Our results show that the rank ordering of tag types is almost identical across these different artists, and consequently, the relative frequencies of musically meaningful concepts such as consonance, color, and dissonance, are also shared.

We also used tags to compare jazz instructional advice with our statistical data. Many of the results confirm generally accepted guidance (jazz musicians predominantly use voice leading), and some extend educational advice (Table II show that all transition types are important). However, some generally accepted concepts were shown to be misleading. The bebop scale is said to facilitate placement of chord tones on down beats. This could be interpreted (for example, by students) that chord tones should be more common on down beats, but the data shows that chord tones played by renowned musicians are, in fact, evenly distributed across beats, and, in fact, are conditionally slightly more common on up beats.

Together, these results show that harmonic tags not only reveal characteristics about the compositional structure of jazz, but do so in a way understandable to practitioners of the art – an important and desirable characteristic when interpreting machine generated results. For this, we believe our findings are useful as a benchmark against which machine generated jazz in the bebop style can be evaluated and compared.

Finally, we provide evidence that harmonically-oriented tags have explanatory power that should not only be of use to students of jazz, but also to the designers of music information retrieval and music generative algorithms. Our approach is analogous to part-of-speech tagging (POS), widely used in natural language processing [27]. Tags provide invaluable syntactic information that is particularly useful in NLP when the amount of data is limited. This is true for many existing low-resource languages (recent examples include, Khasi [28], Kazakh and Turkish [29], and Telugu [30]). Music in general, and jazz in particular are low-resource data, and we expect our tagging system to be a useful and relevant preprocessing step to subsequent training on deep neural nets for generative and MIR tasks related to jazz. In addition to the development of knowledge-based features, Table I provides rank statistics (see [31]) which can serve as a basis for evaluating generative algorithms for bebop style of jazz.

Although the focus of this paper has been on jazz, we expect our approach to domain-motivated feature extraction will also be useful for other Western tonal music genres.

Acknowledgment

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