# MINING CONTRAST PATTERNS IN JAZZ GUITAR SOLOS

**Arne EIGENFELDT**[1] and **Darrell CONKLIN**[2,3]

[1]*School for the Contemporary Arts*, **Simon Fraser University**, Vancouver, Canada
[2]*Computer Science and Artificial Intelligence*, **University of the Basque Country EHU**, San Sebastian, Spain
[3]**IKERBASQUE, Basque Foundation for Science**, Bilbao, Spain

## ABSTRACT

Computational musicology is the part of musicology that employs computational methods for the analysis of music corpora. This paper uses a pattern discovery method to investigate the melodic patterns employed by five jazz guitarists, discovering those that are over-represented in their solos. The paper also compares the patterns of these guitarists with transcriptions of jazz solos of other instruments to determine whether there are particular improvisatory patterns that are over-represented on the guitar.

## 1. INTRODUCTION

In this paper we apply a pattern discovery method to find patterns within jazz guitar solos. Earlier studies on mining of jazz solos have used the WJazzD database [1]: a highly curated symbolic dataset of 456 jazz solos. The database has been the source for prior computational studies of jazz improvisation [2,3]. However, over half of the solos within are for saxophone and trumpet, and guitar solos are barely represented, with only six in the entire database. Therefore, for our study it was necessary to create a new corpus of jazz guitar solos. In this paper, we describe the dataset, the computational methods used for pattern discovery, and pattern discovery results in the form of interesting over-represented patterns. This work represents one of the first computational studies specifically considering jazz guitar improvisation. The work bridges computational musicology with jazz performance practice, as found in corpora of transcribed solos.

This study focuses on jazz guitarists from the post-bop period — Wes Montgomery, Grant Green, Barney Kessel, and Jim Hall — and in addition, on Pat Metheny, a progressive jazz guitarist. Guitarists from the 1950s and 1960s tended to imitate solos from trumpeters and saxophonists of the period, whereas later guitarists – such as Metheny – attempted to explore the guitar as a unique instrument; our motivation was to investigate the actual melodic interval patterns to determine whether this was the case. Another objective of this study was to investigate whether there are instrument-specific patterns in jazz guitar improvisation.

Previous research into improvisation [4] noted that bebop can be characterised as being a shared melodic language assembled from recurring formulas – short, transposable melodic figures that players memorise, vary, and recombine. An individual's style emerges less from novel invention than from which formulas they favour and how they inflect them. Berliner's ethnographic study [5] reframes the same phenomenon from the performer's perspective, documenting how musicians deliberately build a "vocabulary" of figures through years of listening and practice.

Our understanding of improvisation, coming from both a professional and amateur background, recognises that improvisation combines extemporaneous melodic expression with practised pattern exploitation. The musical motivation of our study was not to determine how improvisers structure their solos or develop melodic ideas but rather how patterns are repeated and used in different solos by the same performer.

Young jazz improvisers are encouraged to "learn the licks" of established musicians and to be able to reproduce them in various keys. We recognise that reproducing specific patterns at different transpositions is not a simple task on wind instruments; however, the construction of the guitar allows for transposition by simply moving the hand. For this reason, we believed that pattern-based improvisation would be widely used in guitar solos.

In analysing patterns in music, one must recall that statistical significance does not necessarily imply deep musical significance. As an example, the interval of an ascending major second (a trivial pattern of length one) occurs significantly more frequently in Metheny's solos ($1.5\times$, $p$ =1.5e-18) than in other guitarists. While curious, this is not immediately musically interesting.

Several research questions are addressed in this study: are there melodic patterns over-represented in solos of individual guitarists? Are there differences between the post-bop group (Hall, Montgomery, Kessel and Green) and Metheny's progressive jazz? Are there patterns in jazz guitarists versus other instrumentalists? In this paper, we will present a selection of discovered patterns that we find both statistically significant and musically interesting.

## 2. METHODS

### 2.1 Corpus

We selected the four post-bop guitarists based on their importance to the period and the availability of transcribed solos. For Metheny, with the exception of two solos from the WJazzD database, transcriptions were gathered from various online sites and checked against recordings to ver-

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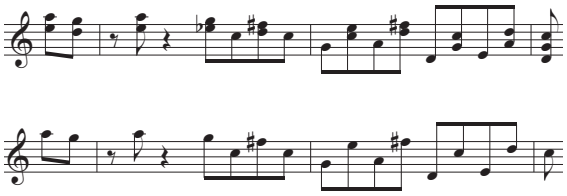
| Guitarist | # solos | # notes |
|---|---|---|
| Wes Montgomery | 5 | 2290 |
| Jim Hall | 4 | 2022 |
| Grant Green | 4 | 2385 |
| Barney Kessel | 4 | 1088 |
| Pat Metheny | 10 | 5655 |
| | 27 | 13440 |

Table 1. The guitar corpus.

ify their accuracy both visually (using music notation software) and aurally.

Because the algorithm used, described below, requires monophonic melodies, editing was required on some solos that used double- or triple-stops; solos that were primarily chord-based were not used. In cases of concurrent notes, the top line was chosen except when the melodic movement occurs in a lower line, in which case the line with the most movement was selected.

An example of our editing decisions is given below: the top line is the actual transcription of pitches played by Jim Hall in *Angel Eyes* m.153-156; the bottom line is our monophonic selection. We argue that listeners perceive the top line in such melodies.



In the case of Wes Montgomery, whose solos often included octaves, we used the top line.

The resulting guitar solo data [1] contains 27 solos from five different soloists, totaling 13440 notes (see Table 1).

### 2.2 Pattern discovery and statistical significance

To study jazz guitar solos, we employ the methods of *contrast pattern mining*. This is the process of discovering patterns whose relative frequency differs significantly from one group of data (a positive set) to another (a negative set). Patterns are variable-length sequences of melodic intervals (expressed in semitones) that occur in the solos. Thus patterns are invariant to transposition, which is very important for mining guitar solos. A pattern may occur multiple times in the same solo, with self-overlaps (occurrences of the same pattern possibly overlapping one another) also counted.

For each discovered pattern, an over-representation factor is computed: the relative probability of the pattern in the positive set divided by its relative probability in the negative set. The *p-value* of a pattern gives the probability that the observed factor can be due to random chance and is done using a Fisher's exact test [6, 7]. An efficient algorithm [6] is used to discover the top-$k$ (lowest $p$-value) patterns in a corpus. In this study, the ranking of the pattern is more important than the exact $p$-value, so $p$-values corrections for multiple hypothesis testing (considering the total number of patterns probed) were not applied.

[1] available for download at `https://tinyurl.com/ykuv2ee7`

## 3. RESULTS

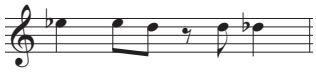
In this section, we describe six results: for each of the five guitarists, the contrast patterns found for that guitarist (pooling all other guitarists as the negative set); and patterns contrasting the guitar solos (pooling all guitarists) versus solos for all other instruments. For the latter, all non-guitar solos from the WJazzD dataset were extracted (450 solos, 196817 notes).

For each partitioning, we mine for the top-10 patterns and further for the top-10 *jumping* patterns: those occurring only in the positive set and never in the negative set. All patterns are required to occur at least twice and in at least two solos in the positive set. This guards against the discovery of patterns that may occur many times but just in a single solo.

Table 2 shows the summary of patterns that will be discussed in the remainder of the paper, with their ranking within the top-10 patterns for the positive group $\gamma$ (prefix J: jumping pattern). The count $t_{\phi\gamma}$ refer to the total count of the pattern $\phi$ in the positive group. The count $n_{\phi\gamma}$ is the number of solos that contain the pattern (one or more times) and $\Delta$ refers to the over-representation of the pattern ($\infty$ for a jumping pattern). The remainder of this section discusses some patterns with score fragments.

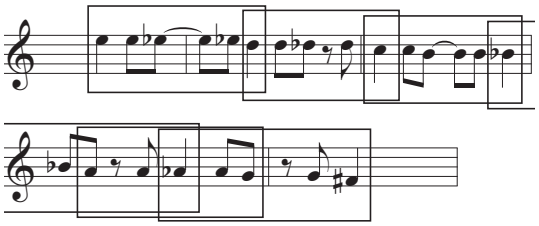
### 3.1 Wes Montgomery

Wes Montgomery's most over-represented pattern [0 -1 0 -1] (J0) is unique to Montgomery – i.e., a jumping pattern, and is a descending chromatic line. The following example can be found in Montgomery's solo in *Blues in F*, m.66-67:



Its subpattern [-1 0 -1] (P2) occurs $16.2\times$ more often in his solos than in the other guitarists.

Like many of the patterns found for all five guitarists, Montgomery will extend this pattern by repetition, creating a much longer pattern of unified intervalic construction. The following example is found in Montgomery's solo in *Blue 'n Boogie*, m.112-116:



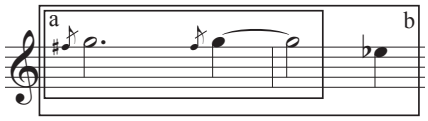
Another over-represented pattern for Montgomery (P3), occurring 19 times in four solos, over four times more often than in other guitarists in the corpus, is [1 -1 1]. Ten of these times, the leading note of the pattern is played as a grace note, and of those, seven will be extended with a descending major third. Overall, the initial grace note in

| $\gamma$ | rank | interval pattern $\phi$ | $t_{\phi\gamma}$ | $n_{\phi\gamma}$ | $\Delta$ | $p$-value |
|---|---|---|---|---|---|---|
| Montgomery | J0 | 0 -1 0 -1 | 10 | 2 | $\infty$ | 2.0e-08 |
| Montgomery | P2 | -1 0 -1 | 10 | 2 | 16.2× | 3.5e-06 |
| Montgomery | P3 | 1 -1 1 | 19 | 4 | 4.2× | 1.2e-05 |
| Montgomery | P9 | 1 -1 1 -4 | 7 | 3 | 34.1× | 2.8e-05 |
| Hall | P0 | 9 | 54 | 4 | 4.1× | 1.0e-13 |
| Hall | P1 | 12 | 30 | 2 | 6.8× | 1.1e-11 |
| Hall | P3 | 8 | 44 | 4 | 3.0× | 2.3e-08 |
| Hall | J0 | -10 9 | 7 | 2 | $\infty$ | 1.7e-06 |
| Hall | P2 | 2 -2 2 -2 2 -2 | 11 | 2 | 62.1× | 9.0e-09 |
| Green | J0 | 1 -1 -2 -2 -1 -2 -1 | 12 | 2 | $\infty$ | 9.5e-10 |
| Green | J2 | -4 -1 -2 5 -3 | 9 | 2 | $\infty$ | 1.7e-07 |
| Kessel | P0 | 3 3 | 28 | 4 | 3.3× | 4.1e-07 |
| Kessel | J4 | 4 4 -2 | 3 | 2 | $\infty$ | 5.3e-04 |
| Kessel | J5 | 3 4 4 | 5 | 2 | $\infty$ | 3.4e-06 |
| Kessel | J6 | 3 3 3 -1 -5 | 5 | 2 | $\infty$ | 3.4e-06 |
| Metheny | P0 | -1 -1 -1 -1 | 79 | 7 | 12.1× | 6.9e-21 |
| Metheny | J1 | 1 -1 -1 -1 -1 | 18 | 7 | $\infty$ | 1.7e-07 |
| Metheny | J2 | -1 -1 -1 -3 2 | 15 | 6 | $\infty$ | 2.3e-06 |
| Metheny | P3 | -4 3 | 91 | 8 | 5.7× | 4.9e-17 |
| Metheny | J6 | -4 3 -4 3 | 29 | 5 | $\infty$ | 1.2e-11 |
| | | | | | | |
| Guitar | P0 | 0 | 1178 | 27 | 1.7× | 1.1e-66 |
| Guitar | P8 | 0 0 0 0 0 0 | 106 | 8 | 2.8× | 5.0e-18 |
| Guitar | J3 | 1 -1 -2 2 1 -1 -2 2 1 -1 -2 2 | 7 | 2 | $\infty$ | 4.4e-09 |

Table 2. Summary of the discovered patterns presented in this paper. Top: individual guitarists vs. others; bottom: guitar vs. other instruments.

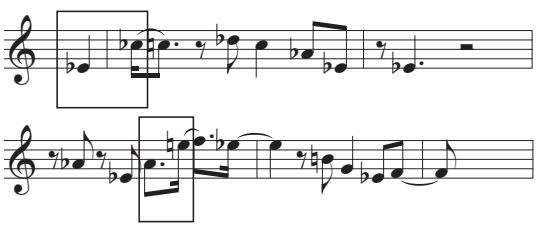
P3 is performed only five times without P9 ([1 -1 1 -4]), suggesting that P9 is a prepared and practised lick.

The following example is found in Montgomery's solo in *Blue 'n Boogie*, m.13-14 (a: P3; b: P9):

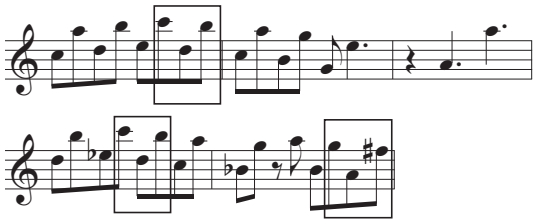



### 3.2 Jim Hall

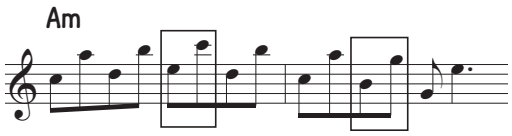
Hall's solos exploit the ability of the guitar to play large intervals as easily as smaller ones. Over-represented patterns in his solos are upward leaps of a major sixth (P0), an octave (P1), and a minor sixth (P3), as well as other combinations of large leaps. For example, Hall begins his solo in *Free and Oozy* with a dramatic leap of a minor sixth, then repeats this interval in the next phrase. This interval is repeated five times in the first chorus of the solo, beginning in m.1:



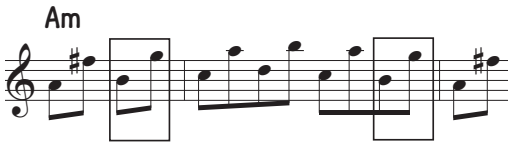
Hall develops these large intervals in his solos; in *Angel Eyes*, he builds on his P0 pattern of a major sixth with the occasional P3 (minor sixth). Hall's transposition of these patterns up and down the fingerboard results in a unique jumping pattern J0 [-10 9] of a descending minor seventh followed by an ascending major sixth, as demonstrated in the following example in measures 66-70.



The insertion of the minor sixth interval (boxed in the figure below), breaking up the consistent major sixth (P0) follows the underlying harmony; while seemingly contradicting our argument that guitarists will shift a pattern up and down the fingerboard, it does suggest that Hall has thoroughly practised his scales as sixths (thus supporting our overall hypothesis that patterns are learnt and practised). This example is from m.66:

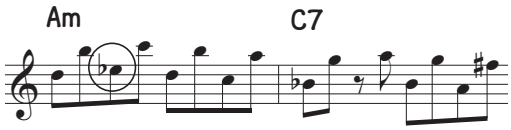



Hall restates the M6/m6 motive later in his solo in m.114, again adjusting the intervals to fit the harmony:

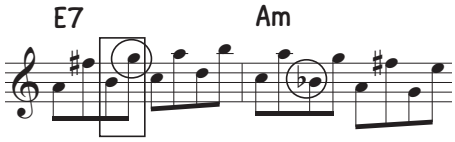



Interestingly, Hall almost immediately introduces chromatic pitches while retaining the consistent intervalic pat-

tern of P0 in his next phrase (the circled note is the non-tonal pitch). This example is from m.69:

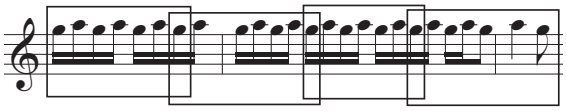



P0 returns as a consistent interval pattern, this time interjecting more non-tonal pitches (circled); this example is from m.90:



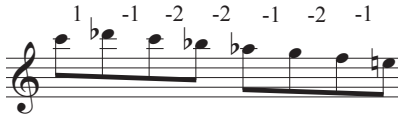

These large intervals occur monophonically in Hall's solos, and are not the result of our editorial reductions.

Later in the same solo, Hall offsets these large intervals with another over-represented pattern (P2): an oscillating major second; this example is from m.137-139:



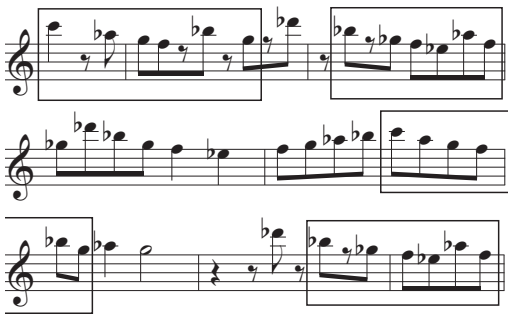
### 3.3 Grant Green

Of Green's ten over-represented patterns, nine are variations or subpatterns of the following descending minor scale approaching from below by a semitone [1 -1 -2 -2 -1 -2 -1] (J0), which is the highest-ranked jumping pattern. The following example can be found in Green's solo in *What Is This Thing Called Love*, m.157:



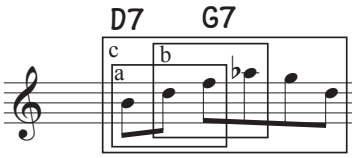

Variations on this occur hundreds of times across the four solos analysed.

Another jumping pattern [-4 -1 -2 5 -3] (J2) in Green's solos is a practised lick, which is first presented four times at the beginning of his solo in *Jean de Fleur*. It occurs two additional times in the solo, as well as four times in *All the Things You Are*:

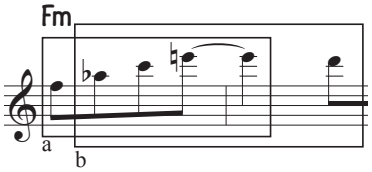


### 3.4 Barney Kessel

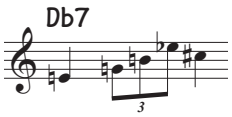
Kessel's patterns display very guitar-like arpeggios, more so than the other guitarists of his period in this study. His most over-represented pattern [3 3] (P0) is a diminished triad arpeggio, which he most often plays over dominant chords outlining upper extensions (such as the flat ninth). He will also interlace two instances of the pattern to construct a fully diminished seventh chord and extend this with another over-represented pattern, [3 3 3 -1 -5] (J6). Beginning this sequence on the sixth degree of the harmony strongly suggests a practised pattern, ending as it does on the next chord's fifth degree. This can be found in Kessel's solo in *Jordu*, m.3 (a, b: P0; c: J6):




Another unusual pattern combination is Kessel's jumping patterns J5 and J4. The former is a minor triad with an added major seventh, often played over minor chords beginning on the tonic; the latter uses what amounts to an augmented triad with a descending turn (a: J5; b: J4). The following example can be found in Kessel's solo in *Minor Mood*, m.53-54:

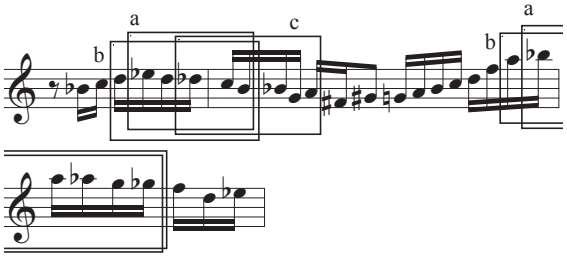



While the above example may seem somewhat mundane, consider this exact combination over a less predictable chord, demonstrating this as being a preconceived pattern combination, as found in Kessel's solo in *Jordu*, m.54:

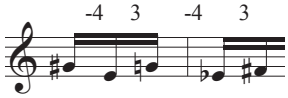



### 3.5 Pat Metheny

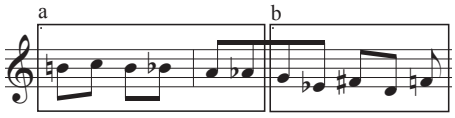
Mining the ten solos of Pat Metheny, we find that he has two distinct melodic patterns that are over-represented. The first pattern [-1 -1 -1 -1] (P0) includes variants on a descending chromatic scale, $12.1\times$ in Metheny ($p = 6.9\text{e-}21$). The pattern P0 (a) often has a prepended ascending semitone (pattern J1, b) and is sometimes appended by a descending minor third and ascending major second (pattern J2, c). The following example can be found in Metheny's solo in *Have You Heard*, m.13-15:




Another over-represented pattern in Metheny's playing is [-4 3] (P3: $5.7\times$ in Metheny), which is often extended to [-4 3 -4 3] (J6). This amounts to a descending chromatic lick of parallel major thirds, a particularly guitar-like pattern. The following example can be found in Metheny's solo in *Third Wind*, m.1-2:



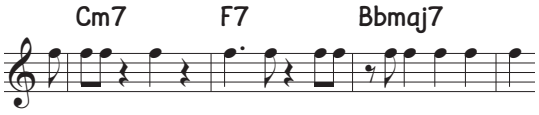

Metheny will often combine these rehearsed licks, as he does in *All the Things You Are* (a: J1; b: J6):



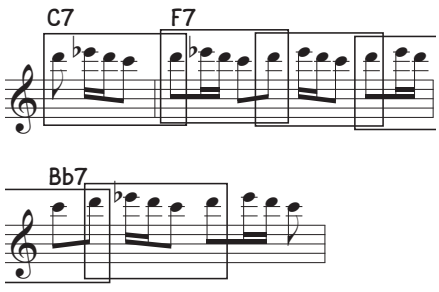

### 3.6 Guitar versus other instruments

Comparing guitar improvisations with other instruments in the WJazzD database, we find several patterns (bottom of Table 2). All 27 solos for the five guitarists contain a single-note repeated pattern (pattern P0); guitarists play a single repeated note (P0) $1.7\times$ more than other instrumentalists, and $2.8\times$ for repetitions of seven or more (P8, occurring in eight solos played by four different guitarists: Metheny, Green, Hall, and Montgomery).

Here is Grant Green's repeated note pattern over several chords from his solo in *What Is This Thing Called Love*, m.50-54:




The notion of pattern repetition, as just presented, is further seen as guitar-specific. Pattern J3, which occurs only in Green and Montgomery, is a threefold repetition of [1 -1 -2 2] over several chords. Here is Wes Montgomery repeating [1 -1 -2 2] several times in his solo in *Blues In F*, m.37-39:




## 4. CONCLUSIONS

Our study has shown that there are specific melodic patterns employed by jazz guitarists Wes Montgomery, Jim Hall, Grant Green, Barney Kessel, and Pat Metheny that could be considered part of their individual style, in that they perform these patterns statistically more often than other guitarists.

We also noted that while Metheny, a progressive jazz guitarist, employs chromatic patterns more than the post-bop guitarists, chromatic patterns did appear in the solos of Montgomery and Hall, suggesting that chromaticism is less style-specific than guitar-specific.

Finally, we discovered a strong preference of the guitarists to utilise single repeated notes when compared to other instrumentalists, and that specific repeated patterns only appear within these guitar solos.

Future work includes a more detailed look at the improvisations of Pat Metheny and comparing his pattern preferences to contemporaneous guitarists, such as John Scofield, as well as other instrumentalists, such as Michael Brecker.

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