A technical look at swing rhythm in music

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Abstract

We investigate swing rhythm in music using computer analysis techniques. Swing is not a genre of music, rather a performance style. A musical piece (data) can be played in swing or straight time. Musical notes and structure are identical in both performances, but the notes' temporal patterns have slight, significant differences between straight and swing performances. We demonstrate an approach for analyzing these differences, and show examples of several styles of swing: American Swing, Brasilian Samba, Jamaican Reggae. Prior swing rhythm research discovered *swing ratio* as a metaphor representing some classic jazz styles of temporal variations in performed music as compared to written music. Our work shows that, in some cases, swing ratio is inadequate to properly model the real patterns of temporal variation. We have extracted details showing that swing exists hierarchically, i.e., the patterns of temporal variation played at one time scale may differ from those played at a slower or faster time scale. We show examples of different instruments playing swing differently from each other, locking together at certain canonical time locations representing standard counting and subdivision of the musical meter. This latter phenomenon has been previously investigated as ensemble swing. The time locking, while precise, may not be exactly synchronized. We refer to this as "playing around the beat." It is a very different musical feature than merely playing sloppy rhythmic synchronization. It is one measure of how "tight" or "loose" a musical performance is.

Introduction

Ask a musician what makes music swing. You will hear that swing is a feeling, and maybe some information about counting or subdividing the beat. Commonly, triplet note subdivision is a feature in swing music, but this is not the entire story or else a waltz, 6/8 or 12/8 meter would inherently swing. Some of these do, and some don't.

We use a cultural rather than technical definition for swing: it is a property of music *as played* which causes listeners to dance or otherwise move their bodies in an energetic rhythmic manner. This definition lets us consider a broader range of music than most prior research into swing rhythm. It also allows us to distinguish between swing and other types of rhythmic expression.

Prior research into swing

Cholakis (1995) cataloged an extensive set of Jazz drummers and analyzed the statistical nature of how each musician swung the beat in a different style. Cholakis extracted the ratio of temporal intervals for notes as played compared to notes as written -- or would be written. It is common for Jazz and other types of popular music to be played by ear rather than from sheet music. Nonetheless, the music has a standard metric form and can be transcribed to tablature based on the meter. If the tablature form is transcribed to MIDI format and played by a computer sequencer, the feel of the music often sounds quite mechanical compared to the original human performance. Some MIDI software allows the user to modify the note timing to re-create the original, or a new form of, swing either algorithmically or by hand tweaking. Software cannot (as yet) completely mimic a human player's swing feel.

Gabriellson (1987 & 2000) has noted that rhythmic variations and expression are almost universal in music, and he reports that listeners generally prefer music played with rhythmic expression to music played strictly by the metronome. This phenomenon applies to popular music, European Classical music, and many non-European musical traditions, such as African and Middle Eastern music.

Waadelund (2004) has linked swing style to body movement, and used video recordings to study the body english of drummers in order to correlate their bodily movements to the rhythmic style being played.

Friberg and Sundstrom (1999 & 2002) have extended Cholakis' swing ratio work. Guoyon (2005) has demonstrated computational signal processing techniques for changing the swing feel in a music sample. Hamer (2000) puts a cultural slant on Friberg's and other's research, as does Birch (2003). Several software companies offer software aimed at training musicians to understand and play various types of swing.

A new form of the STFT spectrogram (short time Fourier transform) as described by Fulop and Fitz (2006) is a major advance in the information processing strategy that we have used in this work. The new spectrogram allows better frequency resolution for a given data set, as well as information unavailable in traditional uses of FFTs and STFTs such as instantaneous phase and frequency.

Many prior researchers show statistical analysis of note events in musical samples. This can be a useful technique, but we assert that the *performance* of music, whether by human or computer, is not a statistical process. Rather, each note event relates to other note events in very specific ways, and metaphors other than statistical analysis should be used as appropriate. An obvious example is the hierarchical relations between repetitive groups of note events at different time scales which give rise to common musical features such as meter, beat and subdivision. These can be statistically analyzed for something like measuring the change of tempo or simple swing ratio, but it is a mistake to think that the meaning of the music is statistical. Rather, the meaning is in the specific details of the many complex forms of the swing.

Analysis methods

We use standard DSP (digital signal processing) techniques and relatively simple pattern recognition to extract useful details in the music which is sufficient for our purpose. A short audio loop is made which is (ideally) free from any audio artifacts or glitches in the rhythmic timing as the sample loops from the end back to the beginning. Our experience is that anomalies as short as five or ten milliseconds are sufficient to be perceptible as a break in the rhythmic flow. This is distinguished from editing artifacts such as may cause an unnatural transition in the audio waveform. For these reasons we always edit at zero crossing points in the audio waveform. This is not always sufficient to avoid all artifacts which can be perceived either explicitly or intuitively by a well trained human ear. Loops are ten to twenty seconds long, which is sufficient to understand the rhythm and swing feel, and also short enough that our software doesn't encounter memory limit problems.

First we process each musical sample loop to make a spectrogram. Choice of frequency resolution and STFT window overlap may be different from sample to sample, but we have found that 2048 point FFT and three to ten millisecond window overlap are well suited to many samples. Visual inspection of the spectrogram allows us to choose which frequency bands are likely to contain the information relevant to distinguishing musical notes played by various instruments. Sets of the (possibly overlapping) frequency bands are summed to obtain time series plots of the audio power in the several bands. The frequency bands are plotted (`chkdot`) in a time aligned fashion to show relative timing of musical events in various bands, played by different instruments. The `chkdot` waveforms are marked for peaks representing the musical events, and the time locations of the sets of events are extracted. The extracted time locations are plotted in a new type of plot (`diffdot`) which shows the time differences (delta time) between notes. Musical meter and subdivision are chosen from the `chkdot` event information and marked in a straightforward way on these plots. The `diffdot` plots show the variations in time locations of repetitive musical events extracted from the `chkdot` plots, such as pulse, backbeat and swung notes.

Musical samples

We give analysis results for several swing music tunes: *It Don't Mean a Thing (if it ain't got that swing)* by Duke Ellington & Irving Mills, performed by Duke Ellington & Louis Armstrong (1962) ; *Graceland* by Paul Simon (1986) ; *Fever* by Eddie Cooley & John Davenport, performed by Ray Charles and Natalie Cole (2004) ; *Stir it up* by Bob Marley, performed by Bob Marley and the Wailers (1973) ; examples of Brasilian samba batucada music from the CDs *Grupo Batuque Samba de Futebol* (2004) and *Os Ritmistas Brasileiros Batucada Fantastica* (1963/1998) by Luciano Perrone e Nilo Sergio.

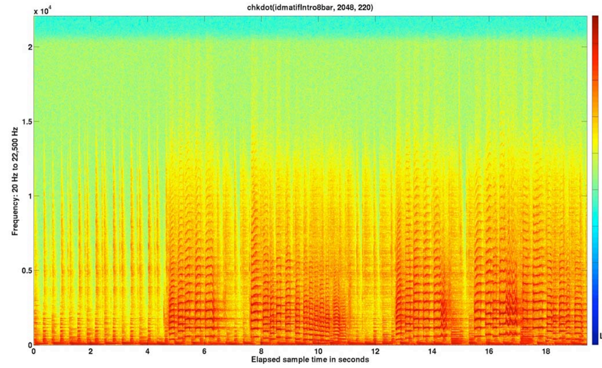

Fig 1. Spectrogram of Intro for *It don't mean a thing (if it ain't got that swing).*

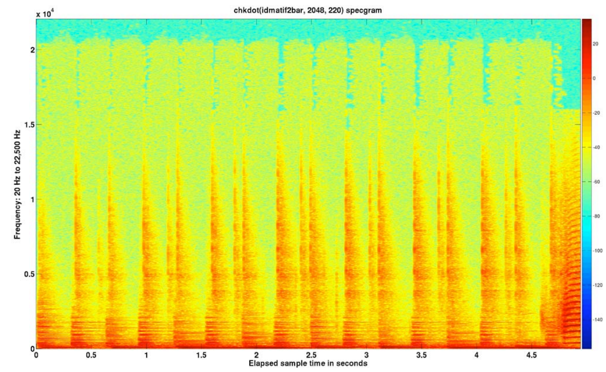

Fig 1a. Close-up showing hi-hat cymbal.

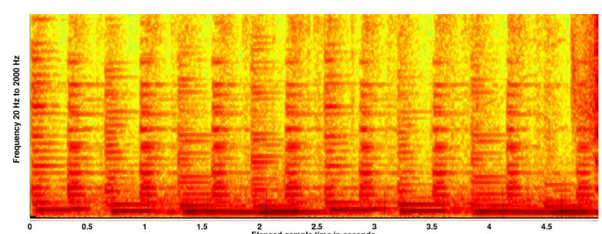

Fig 1b. Close-up showing piano and drums.

Figures 1, 1a and 1b show spectrograms of the intro to *It Don't Mean a Thing (if it ain't got that swing)*. Figure 1 is the overview of the 19.3 second sample, showing the entire Fourier spectrum up to 22,050 Hz (half of the

CD sampling rate of 44,100 samples/sec). The main feature of the first few seconds is high frequencies of the hi-hat cymbal playing the classic *tchzzz-tch-ta-tchzzz-tch-ta-tchzzz...* jazz swing rhythm. The bass and piano parts are in the low frequencies as a thick red mass. Louis Armstrong's trumpet dominates the remainder of the sample, clearly revealing the harmonic structure, timing and pitches of the notes. Figures 1a and 1b show close-up views of the cymbal and piano/bass section. The inherent technical limitations of Fourier analysis are clear in the coarse resolution of the piano and drum low frequency data. Human perception of high frequency parts of the audio spectrum may be fairly approximated by Fourier series, but the physiology of low frequency hearing is really not much like an FFT. Fulop and Fitz's new spectrogram technique would reveal much useful information that is obscure in the current figures.

We are able to extract the rhythms played by the bass/piano and hi-hat and then plot the corresponding frequency bands in Figure 2 (`chkdot`) as time series. Note events are marked as described earlier, and the temporal locations are collected. This sample was analyzed using 10 millisecond temporal resolution. This is fine grained enough to accurately measure the timing of note events in this song but other songs require better time resolution. The delta times are plotted in Figure 2a (`diffdot`). The musical pulse note events, played by piano/bass, appear at the top, and the hi-hat syncopation is in the lower part of Figure 2a. Notice in particular that the pulse is not uniform. Rather, it alternates between slight pushes on the beat and slight pulls -- i.e. the notes are intentionally *not* played in a strict mechanical metronomic style. The backbeat (1/2 of the pulse) and swung note (1/3 and 1/6 of the pulse) deltas are more uniform than the pulse, indicating that these syncopated notes closely follow the variation laid down by Duke Ellington's piano. Keep in mind that the `diffdot` plot is the time difference between notes, and should not be interpreted as mirroring standard musical tablature form. The `chkdot` plot does correspond to the subdivision representation of tablature.

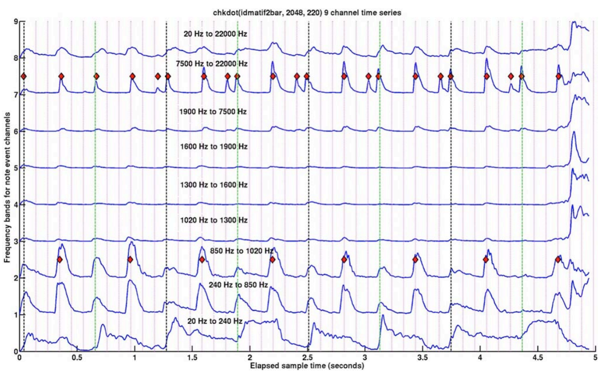

Fig 2. `chkdot` plot: note events by frequency.

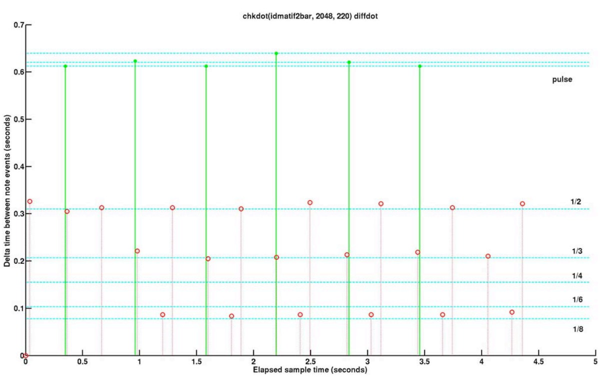

Fig 2a. `diffdot` plot: note event time deltas.

Since this song must be regarded as one of the most fundamental swing tunes of all time, we conclude that the triplet subdivision which is clearly shown in the `diffdot` plot is an important feature of swing style. What is new is the evidence of time variation played in the basic pulse of the rhythm. We examine this feature more closely in subsequent examples. While a triplet subdivision can be reasonably written in tablature notation, we are unaware of any similar notational device for indicating the variation of pulse timing.

Graceland by Paul Simon is a pop tune that mimics the feeling of riding on a railroad. A prominent rhythmic feature is the song's strong backbeat, but without any great sense of the classical jazz swing feel. Nonetheless *Graceland* elicits a very bouncy bodily response. Figure 4 shows a spectrogram of the full audio sample, while Figure 4a shows a close-up of the bass and drum parts. The rhythm in the low frequencies is more clear in this sample than for *It don't mean a thing*.

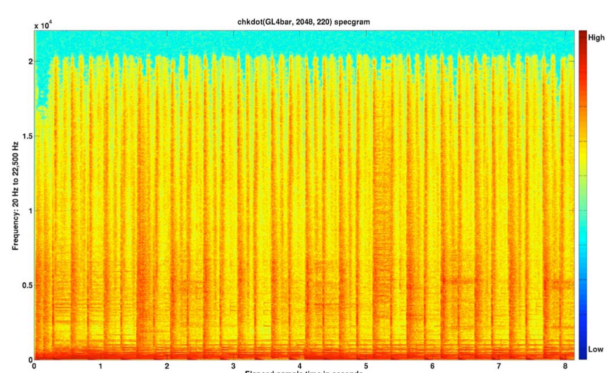

Figure 4. Spectrogram of *Graceland* intro.

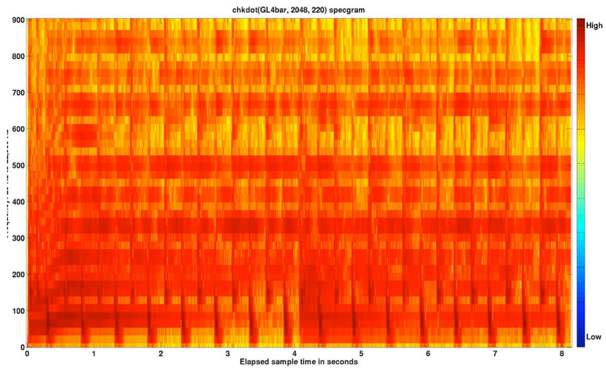

Fig 4a. Close-up showing bass and drums.

Figure 5 shows the time series plots of note events for ten frequency bands. The bass and drum parts provide the pulse, and the secondary note events are extracted from the high frequencies which are the attack envelope of the electric guitar strumming. We used a triplet subdivision in the `chkdot` plots, looking for swing, and were surprised to find that all note events are better represented by a quarter note subdivision scheme -- hence half of the electric guitar notes fall between the triplet subdivision lines. The `diffdot` plot reveals the swing feel for this song. Both the pulse and the rhythm guitar show a repetitive pattern of pushing and pulling the time locations of the quarter note events. There is a substantial amount of variance to the time variations, especially in the beginning of the pulse, which indicates a short term tempo uncertainty. The rhythm guitar is much more consistent in the short/long variations of note timing, well synchronized to the pulse. There is no evidence of any triplet subdivision in note timing variations. The variance of time deltas gives this song a fairly loose feel, but no sense of rhythmic sloppiness, due to the consistent repetitive pattern of time variation.

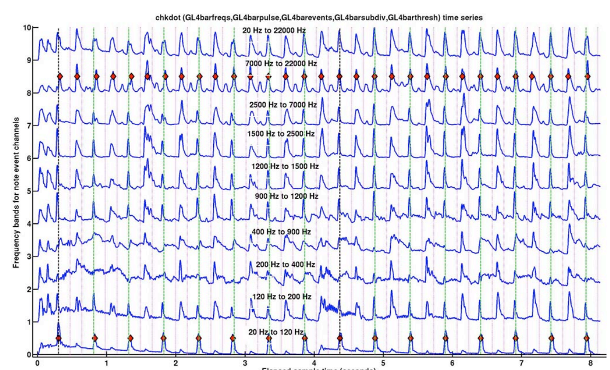

Fig 5. Ten frequency band note events.

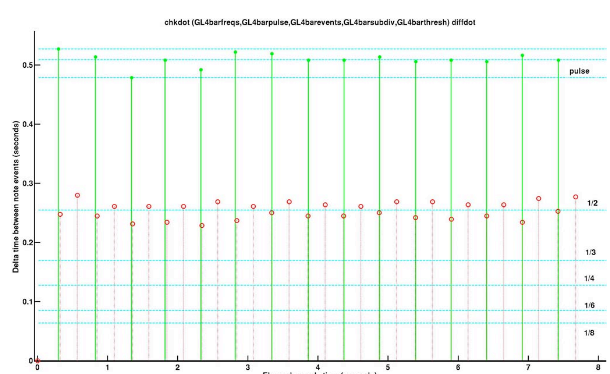

Fig 5a. `diffdot` plot showing time variations of drum/bass pulse and rhythm guitar.

Fever is a classic R & B song with a strong backbeat. Ray Charles' 2004 version is played in a very tight, straight rhythmic style. Despite its almost clockwork precision, this song is never boring and led us to a secondary defining feature of swing (beyond inducing body movement). We found that a 14 second loop made from this recording could play endlessly and after more than an hour, still sounds incredibly fresh. This discovery was made during one of our research review meetings. A sample which becomes perceptually tedious after only a few repetitions almost certainly does not swing.

Beneath the excellent musicianship, we found that there exists a strong triplet element to the rhythm. The conga plays around the backbeat which is marked precisely by Ray Charles' finger snaps. About half of the conga note events are on triplet pickup beats or following beats to either the downbeat or the backbeat. Unlike *Graceland* or *It don't mean a thing,* this sample shows virtually no rhythmic looseness. The conga, drums, finger snaps, bass guitar are synchronized with each other to a precision of better than 15 milliseconds in almost all cases. Contrast this precision with *Graceland*'s intentional variations of 50 to 80 milliseconds, and *It don't mean a thing*'s somewhat random looking variations in the 20 to 40 millisecond range.

Figures 6, 6a and 6b show the familiar set of spectrogram, time series event plots, and `diffdot` diagram. Subdivision of the meter in the time series plot is a four beat pulse phrase with six subdivisions of the pulse. Thus, the downbeat, backbeat and triplet temporal locations are marked. Finger snaps and conga beats land exactly on these time ticks. A few note events can be seen on quarter note

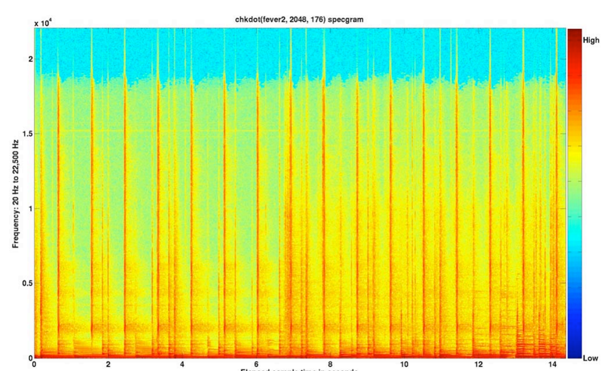

Fig 6. Spectrogram for *Fever.*

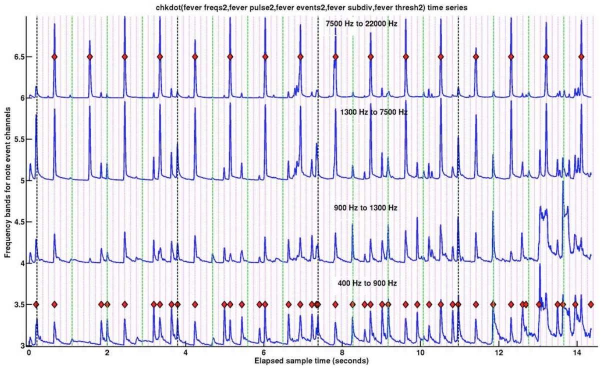

Fig 6a. Time series event plot for *Fever.*

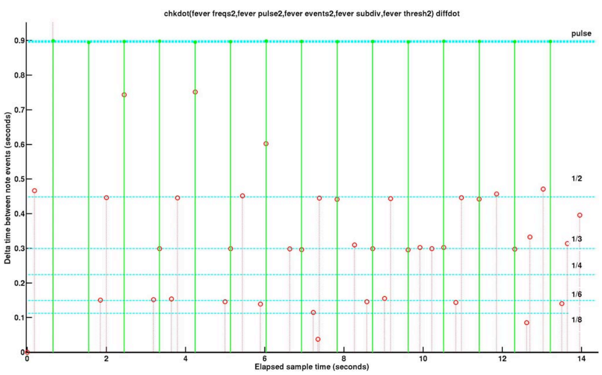

Fig 6b. `diffdot` plot for *Fever.*

locations, but these are rare. The precise clusters of note events on the pulse, backbeat, and triplet time lines in the `diffdot` plot is evident. There is an absence of note events on the quarter note line, just as there was in *It don't mean a thing*.

A very remarkable aspect of this recording can be seen in the close-up `diffdot` plot showing the pulse only, which is Ray Charles snapping his fingers on the backbeat. It is obvious from the normal `diffdot` plot compared to *Graceland* and *It don't mean a thing* that the variations in the pulse event time deltas is much greater on those two samples than on *Fever*. The close-up shows that Ray Charles finger snap time deltas are less than 5 milliseconds. Given the tight rhythmic style of this recording, and the fact that Ray Charles was one of the 20th century's best musicians, we believe this `diffdot` plot represents an important data point regarding the limits of human time perception.

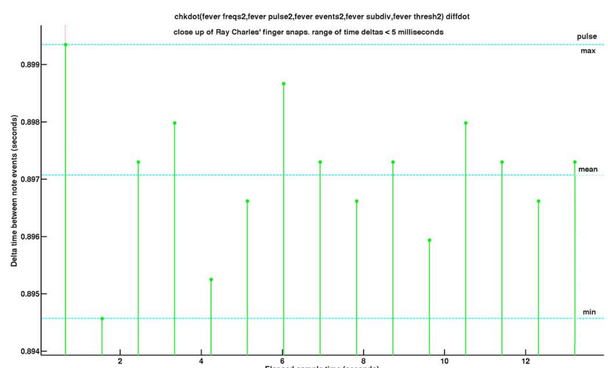

Fig 6c. Close-up `diffdot` plot for the pulse note events in *Fever.*

Reggae music from Jamaica is characterized by complex rhythms, many of which explicitly use the *absence* of a note event as a rhythmic anchor. In American music, note events on the downbeat or backbeat typically anchor the rhythm at the 1 or 3 beat of a 4 beat measure. In Reggae, the downbeat is often not played by any instrument, and other canonical beat locations may also be demarcated by silence, followed quickly by several drum beats in a complex rhythm that may *end* on the next canonical beat. Detection of rhythms with an empty note event as an important feature of their pattern is a challenging task, both for musicians and computer algorithms. Our counting and subdivision scheme was designed for more conventional rhythms, and does not satisfactorily extract the full rhythmic structure of Reggae. Nonetheless, we had some success and show these results here.

Stir it up begins with a very tight and clipped *kip* (a Reggae guitar rhythm) heartbeat played by Bob Marley on electric guitar. As other instruments join in, a sparse and relatively simple sounding gestalt emerges, and the kip is revealed as a backbeat, whereas initially it could be easily interpreted as the downbeat. The rhythm has a slow but insistent quality which we identify as a swing style, although very different from the samples we've looked at so far. Many of the note events are closely aligned with quarter note beat locations, and the rhythm shows no discernible triplet subdivision in the parts we were able to analyze. The time series plot shows the second beat of the kip to be very slightly lagging the canonical quarter note location. In the middle of the song, the kip is played with three notes instead of two, all nearly equally spaced in time. Some of the drum beats happen very precisely on subdivisions which are apparently 1/64th notes, if the kip is taken to be quarter notes. Professional musicians recognize our interpretation of this extreme precision as valid, saying that Reggae is played in a very tight and straight subdivision style. Despite having no obvious triplets, and using a very straight subdivision, *Stir it up* has strong swing feeling. It is not clear to us exactly where this swing lives. Perhaps better DSP and pattern extraction techniques will shed light on this question.

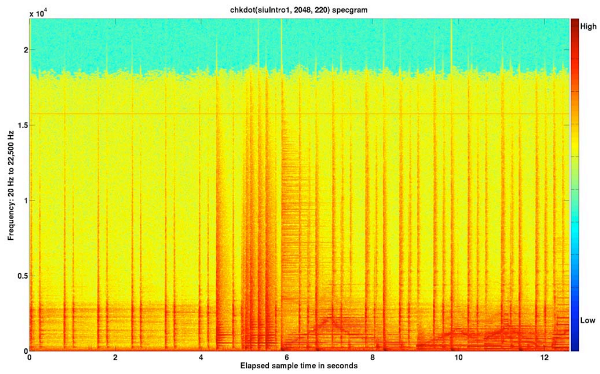

Fig 7. Spectrogram for *Stir it up*.

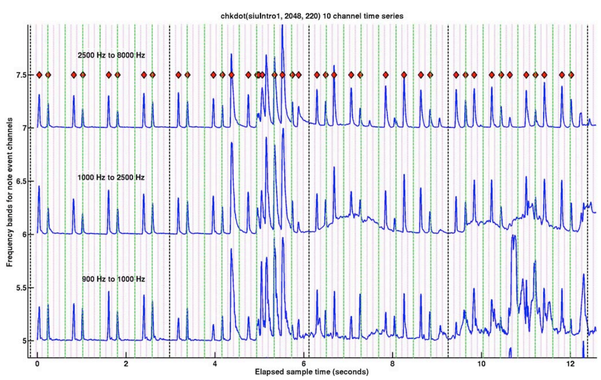

Fig 7a. Time series for *Stir it up*.

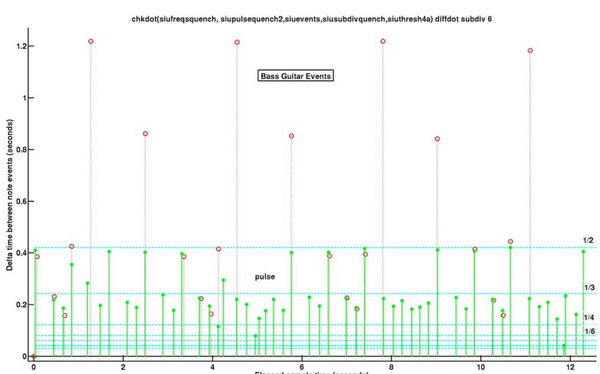

Fig 7b. `diffdot` plot for *Stir it up*.

The `diffdot` plot in Fig 7b shows the mismatch of the Reggae rhythms with our counting and subdividing approach. The timing of the note events does reveal both substantial complexity and consistent repetition of some rhythmic themes, and some of these patterns would likely explain the Reggae swing style. Future work may clarify this.

Swing may include complex rhythmic patterns, but also exists in the context of relatively simple rhythms. This is well illustrated in a basic Brasilian rhythm, the *pandeiro batida*, literally "beating pattern of the pandeiro." The pandeiro is the national instrument of Brasil and is approximately the same as a tambourine in American music. The tambourine is also found in many other musical traditions, but the Brasilian pandeiro has several playing styles which are unique. The basic pandeiro batida is a simple 1-2-3-4 pattern played continuously with slight temporal and accent variations that denote which phrase of a larger pattern is being played. This pandeiro batida is invariably taught as straight time: *one-ee-and-uh* played with thumb (*one*), fingertips (*ee*), palm heel (*and*), fingertips (*uh*), over and over. This batida is both taught and written as a succession of evenly spaced notes, but playing in Brasilian swing style (called *swingee* -- swing-ghee) is far removed from even spacing. We next analyze one example of pandeiro swingee.

The spectrogram clearly shows the basic simplicity of this rhythm. The time series plots show how the note events line up to a standard four beat pulse having a six beat subdivision, which gives vertical lines on the exact triplet and quarter note time locations. The pulse is shown in the lower frequency band which is the thumb hitting the skin causing a low thump. All four notes appear in the upper frequencies which pick up the metallic jingles of the pandeiro. The *uh* note is consistently played on an exact triplet pickup to the pulse. The second and third notes (*ee* and *and*) are played in two very odd locations in the first half of the phrase. Neither of these is played on either a triplet, quarter or eighth note location, and there are slight time variations between repetitions of the basic batida. The pattern of these time variations is consistent by some measure, since in the `diffdot` plot the pattern is clearly a repeating waveform, rather than some kind of random pattern. The `diffdot` plot shows a complete absence of a backbeat (1/2 of pulse) and the presence of a note timing interval of 1/4 of the pulse. This would be a standard quarter note in tablature *if* the time location of the note events were on the canonical quarter note subdivision of the meter which is not true of any of these note events. The `diffdot` pulse shows the familiar push/pull on the canonical downbeat time locations, although in the time series plot, this is a subtle feature.

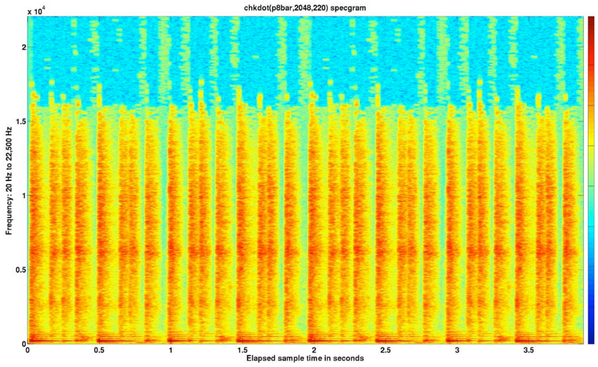

Fig 8. Spectrogram of *pandeiro batida*.

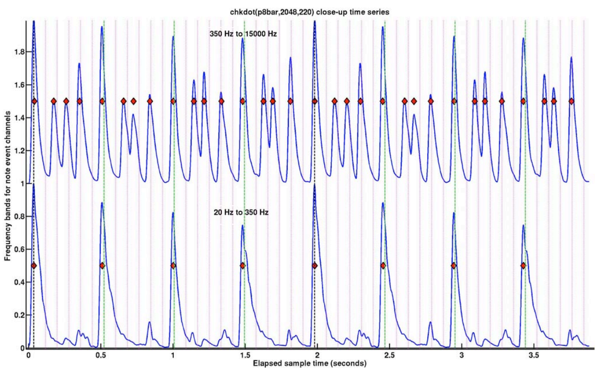

Fig 8a. Time series plot of *pandeiro batida*.

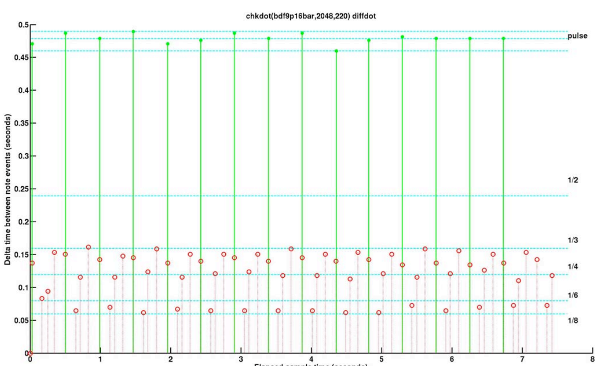

Fig 8b. `diffdot` plot of *pandeiro batida*.

There are a variety of swingee styles that are used to play the basic pandeiro batida. As in American music, there are probably as many styles of swing as there are drummers or pandeiro players. Brasilian swingee clearly has a very different feature set than American swing, even in this simple example.

Many percussion and drum note events have a very sharp and precise onset, making them easy to identify by our approach. Some percussion and drum notes have a much less precise sound. We use the term shuffle to describe a wide range of swing rhythms played in this style. Shakers, brushes on a snare drum or hi-hat cymbal, caixa, afoxe, guiro are all examples of shuffle instruments. Single events can be identified, but overall there is a feeling of blurring and blending of each note event into the next. The meter of the rhythm is defined by the loudness peaks or other identifiable but somewhat temporally ambiguous events. Shuffle is an odd combination of vagueness and precision, difficult to describe with language.

Note ID is more difficult for these less precise musical events, and marking the onset time locations precisely can be subject to interpretation of how the rhythm feels. The standard Brasilian ganza (shaker) rhythm usually has a noticeable snap that precedes the downbeat, but the remaining notes are more blurry. The snap gives a precise anchor to the rhythm which makes the blurry parts sound well integrated to the ensemble swing, rather than sounding as if played carelessly. The spectrogram in figure 9 shows how diffuse the audio is, although note events can be seen fairly clearly. The time series plot shows considerable complexity in the waveforms in all frequency bands. The pulse in the low frequency is played by the Brasilian bass drum, called a *surdo*. The `diffdot` plots the swingee timing variations in both the pulse and secondary events tracks.

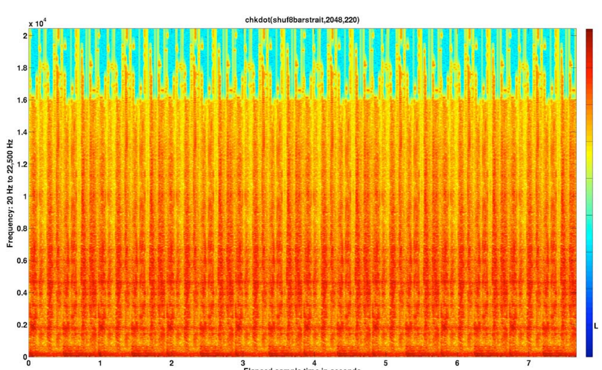

Fig 9. Spectrogram of shuffle rhythm.

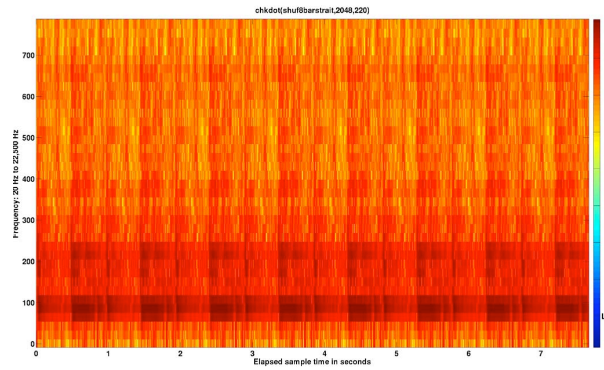

Fig 9a. Close-up of low frequencies.

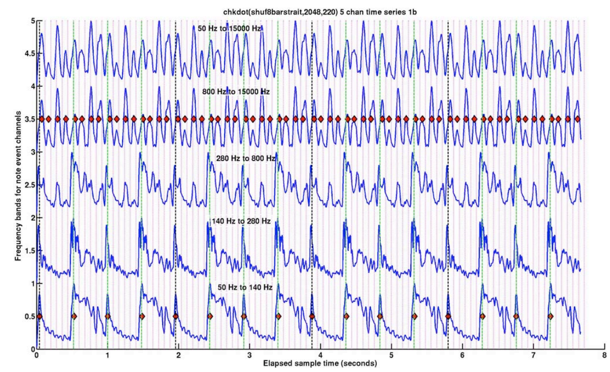

Fig 9b. Time series of shuffle rhythm.

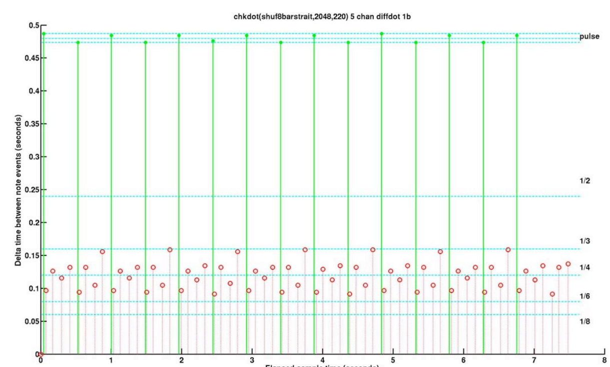

Fig 9c. `diffdot` plot of shuffle rhythm.

We now look an example of complex interaction between two instruments in some detail. The pandeiro plays a duet with a *tamborim,* a small Brasilian hand drum generally hit with a stick. The tamborim plays many of the most complex rhythms in samba. The basic rhythms are often difficult, and the interpretive timing is very fine grained, typically 10 to 20 millisecond excursions from canonical beat locations..

Figure 10 shows the pulse played by the pandeiro, and the *desinha* (design, a Brasilian term for complex rhythmic ornament) played by the tamborim. In the upper plot when the tamborim starts playing, it is not at the standard beginning of the batida. Instead the drummer plays a variation on a portion of the second half of the entire tamborim phrase, which leads into the downbeat. The downbeat is indicated by the green marker at time location 1700, except there is a further variation -- it is not the primary downbeat but the offbeat, so the tamborim is playing on the opposite side from the pandeiro. It is very common in Brasilian music for some two phrase batidas to be played with the two phrases swapped. This is analogous to the 3-2 clave and 2-3 clave style in Cuban music. Swapping the sides gives a different feel, usually more syncopated if the unfamiliar variant is played.

The tamborim batida is very syncopated even when played straight. The “standard” place to start the basic tamborim batida is at note event #6 in figure 10 at temporal location 1700, very slightly ahead of the beat. Many batidas have beats played ahead of the standard subdivision beat, and/or also slightly ahead of or behind the note events of other instruments. In this example, at this temporal location, the pandeiro plays about 30 milliseconds ahead of the standard downbeat, and the tamborim plays about 15 milliseconds ahead of the pandeiro. This technique is used to give a push to the feeling of the rhythm by both instruments. A few beats on either side of the 1700 point, both instruments play notes exactly on a standard subdivision. The feeling of this pattern is consistent throughout the sample which is several minutes long.

Looking at the two sets of three evenly spaced notes starting at 1700 and 2000, observe that the first and third beats are slightly ahead of where they would be if played exactly according to standard subdivision. These beats push the rhythm slightly and give a somewhat more energetic feeling to the music than if they are played straight. In this case, these two tamborim note events are also accented, further emphasizing the push to the rhythm at these two time points. The combination of time push and accent are caused by the tamborim player putting a little extra "juice" into the rhythm for these note events. (Waadelund, 2004) has studied the relation between this type of "body english" and the rhythms played by drummers on drum kits. The investigation of the relation between motion and rhythm started in the early 20th century. (Seashore, 1938) and (Gabrielsson, 1987) both include a variety of reports, insights and opinions about this phenomenon.

In our example, the tamborim plays the first beat right on top of the pandeiro on the "real" downbeat, instead of playing at the "standard" temporal location for the note. This portion of the batida starts its repetition at the ninth event location (time 2000, triplet pickup to downbeat), just before the main downbeat, marked by the black line at time 2050. You can see that the first beat ordinarily is on the triplet pickup to the downbeat, and the next two beats are almost exactly evenly spaced on the subsequent triplet time points. The slight variations from playing exactly on temporal locations that correspond to a standard subdivision are part of the swingee style. While there is some looseness similar to the *Graceland* example, generally Brasilians play these slight temporal variations quite precisely, consistently and intentionally.

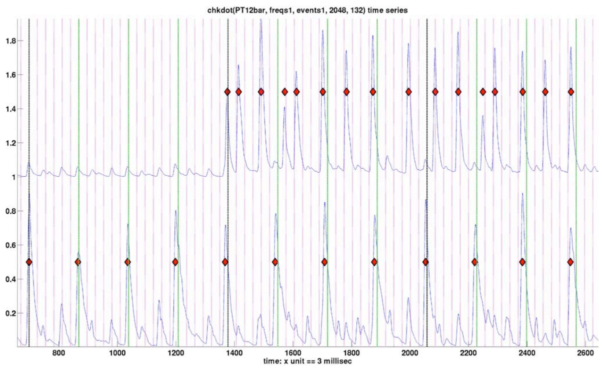

Fig 10. Pandeiro pulse and tamborim *desinha*

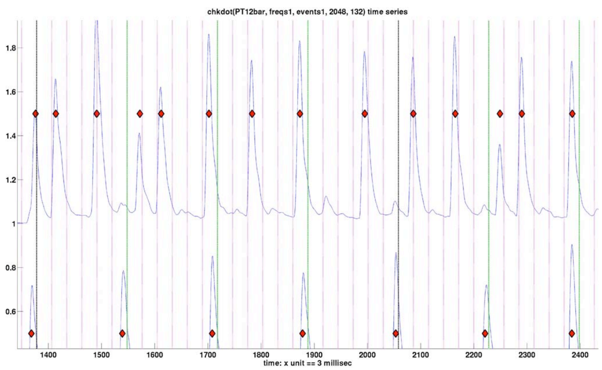

Fig 10a. Close-up showing micro-timing

Conclusions and future work

Swing is a far more complex part of the musical landscape than reported previously in many of the purely technical results from the academic literature. We have analyzed swing rhythms in American, Jamaican and Brasilian music. Some of these are simple enough to allow a complete assessment of the musical features which give rise to swing feeling. Others point in the direction of subtle complexities that require improvements to our pattern recognition and signal processing techniques in order to fully characterize the swing details. There are many other musical styles which have swing characteristics including Cuban, Middle Eastern, African, Funk, Hip Hop. Our analysis results clearly point to a basic inadequacy of standard Euro-American musical tablature notation to annotate many of these rhythmic styles. Comments and observations from professional musicians agree with this notational limitation. For the purposes of musical analysis in the context of music information retrieval (MIR), we feel that it is more fruitful to omit most attempts to render a musical performance as tablature. It would be both more practical and accurate to maintain the information in a form which is close to the actual audio data, and the information features which can be extracted from such recordings.

Appendix: Swingee notation

We have devised a novel form of notation intended to be more informative for playing swing style than is standard tablature notation. A simple visual rendering in the context of standard notation can show timing details we have described. Figures 11 and 11a show this idea using tablature for a pandeiro batida as an example. The pandeiro batida is rendered as straight quarter notes, which is how it is usually taught. Note events which should be played ahead of the standard beat are shown with a red leading edge. The amount of red indicates the amount of temporal variation from the beat. Since the triplet pickup to a downbeat, backbeat or offbeat is an important special case, we indicate a perfect triplet subdivision by including a “3” as a footnote to the note glyph in the tablature. Additionally, we color the triplet blue to indicate its special status.

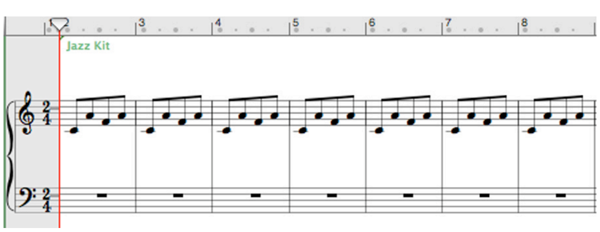

Figure 11 Standard Notation for Pandeiro

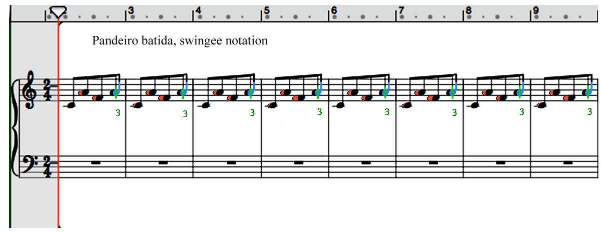

Figure 11a Swingee Notation for Pandeiro

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Online resources:
http://www.makemusic.com/practice_tools.aspx
http://www.majorthird.com/
http://flat5software.com/
http://www.red-sweater.com/clarion/
http://fastrabbitsoftware.com/eartraining.htm
http://homepage.mac.com/ronmiller2/RonsSite/software.html
http://www.lpeters.de/
http://www.cope.dk/
http://www.pandora.com/
http://www.musicip.com/
http://www.wizoo.com/
(original maker of *Darbuka* and *Latigo* software, now owned by digidesign.com)
http://www.tlafx.com/

Discography

Louis Armstrong & Duke Ellington *Louis Armstrong meets Duke Ellington* (1962)

Paul Simon *Graceland* (1986)

Ray Charles *Genius Loves Company* (2004)

Grupo Batuque *Samba de Futebol* (2004)

Luciano Perrone e Nilo Sergio *Os Ritmistas Brasileiros Batucada Fantastica* (1963/1998)