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Research-Grade Acoustic Analysis Determining precise and objective note duration and musical notation for the samba rhythm

By Jonathan Gregory and Sam Matteson

Latin percussion rhythms are often performed in a manner at variance with the notation of the score. Percussionists sometimes say that you just have to *feel* the rhythm. The authors—an experienced percussionist and a physicist with acoustic interests, respectively—undertook an investigation in which a percussion groove characteristic of Brazilian music was recorded and subsequently analyzed using research-grade acoustic analysis software to determine the precise and objective duration of each stroke. Their goal was to establish the objective note values and to suggest alternative music notation more accurately reflecting the standard performance.

PERFORMANCE AND RECORDING

The instrument used in the investigation is a 6-inch Brazilian frame drum called tamborim, which played 16 measures of the traditional samba rhythm—a pattern of four strokes. The tamborim is held by the left hand on the rim and is faced like a mirror, while the right hand strikes the head with a flexible stick (usually a bundle of three wrapped with a grip).

Playing the tamborim requires a unique technique of flipping or rotating the instrument at approximately 180 degrees or less; on the third stroke the player flips the instrument to where it faces down and strikes the head with an upstroke instead of a downstroke. This technique is used to minimize the effort of playing consecutive sixteenth notes with one hand at a fast tempo. Consequently, the use of this technique exacerbates the *swing* intensity.

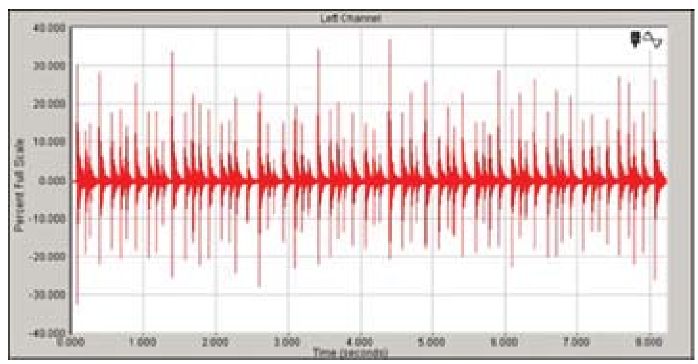
The performer exercised particular care to maintain a constant tempo using a digital metronome set to 120 beats per minute and, at the same time, to record a sample of the rhythm using a DAT recorder.

ANALYSIS

The authors employed a commercially available acoustic analysis software package (SpectraPLUS 2.32, a PC-based FFT spectral analysis program produced by Sound Technology, Inc.) to analyze the time series. In Figure 1, a 16-bar sequence appears.

The vertical axis corresponds to the digitized recorded signal from the sound pressure, while the horizontal axis represents the time in seconds. The signal was digitized at a sampling rate of 44,100 Hz at a resolution of 32 bits. Thus, the ultimate time resolution is, approximately, 0.04 milliseconds, according to the Nyquist criterion.

Figure 1
The time series of an approximately eight-second sample of tamborim rhythm.



In the present analysis, however, the investigators determined the onset of the recorded stroke to be a much more relaxed precision of one millisecond by placing a cursor at the instant of the time series where they determined the initiation of the sound of the stroke to be and recording the value. They identified the start of the stroke as the point where the signal first departed from the baseline. A clear point of the inflection appeared in all cases. Multiple examination of the same features demonstrated that the measurement of the time of the stroke were accurate to better than one millisecond, the limit of the precision. The primary variation in the onset, however, is rather due to the small but inevitable human imprecision of playing the rhythm, as we will see shortly.

An FFT analysis of the sound of the tamborim identified a harmonic series with a significant amount of inharmonic noise, particularly in the 7 kHz to 10 kHz range. Nevertheless, a strong sense of pitch was achieved for a frequency of approximately 292 Hz, a value near D_4. On the other hand, the sound rapidly dampened, dropping by about 15 dB in the first ten milliseconds and later by a more leisurely 0.16 dB per millisecond, the latter value consistent with a reverberation time of 0.37 second, presumably due to the room in which the recording was made. Since the tempo was such that the strokes were spaced approximately 100 milliseconds apart, the baseline had returned to a level of less than one percent of the initial sound level intensity before the next stroke.

Thus, the error in determining the initiation of the subsequent stroke remained below the level of the precision chosen, namely one millisecond.

RESULTS

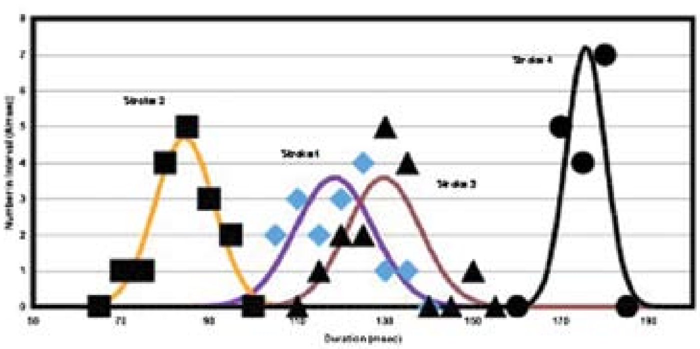
A sixteen-bar sample lasting approximately eight seconds was analyzed. The investigators determined the time between the beginning of each stroke and the subsequent stroke; a histogram of the result is shown in Figure 2. The distribution of the number of notes within a given duration interval (±2.5 millisecond) are plotted versus the duration for the four notes in the measure. Also appearing are plots of normal distribution with the same mean and standard deviation for each of the four strokes in the measures. In Table 1 we also present the mean and standard deviation data for the sample in milliseconds and as a fraction of a standard sixteenth note (duration + 125 msec).

Table 1

Stroke	Duration (ms)	Fraction of ♪ in %
1	116 ms	93%
2	84 ms	67%
3	125 ms	100%
4	174 ms	138%

The histogram illustrating the distribution of the duration of the strokes or the note values for the time series is shown in Figure 2. The second stroke in the measure (Stroke 2) is abbreviated, pushing the rhythm ahead of the beat. Strokes 1 and 3 are very nearly even and equal to the standard sixteenth-note value. Stroke 4 is long enough to return the beginning of the next measure to the downbeat. The mean and standard deviation for each of the four strokes appears in Table 1.

Figure 2



CONCLUSION

The swing is a rhythmic interpretation or distortion of what is actually written. In terms of musical notation, the *swing* is a temporal deformation of given note value. The *swing* is very natural for people who reside in the *Escolas de Samba* (location where the samba gatherings happen) communities, because they grew up listening to samba. The rhythm has become so engrained in the culture that even non-percussionists are able to tap a samba rhythm on the table with the right feel.

The skeleton or the subdivision of the samba rhythm consists of four sixteenth notes with an accent on the first and last partial (this is a common notation used in many books today). See Figure 3.

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- The applicant must be visible throughout the submitted performance(s).
- The DVD must be an ensemble performance.
- The performance may be in any musical style.
- Applicants will be judged on musicality, ability to contribute to the group performance and overall quality of tempo, time, style and musical interaction.
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Deadline: All materials must be postmarked by March 15, 2009.

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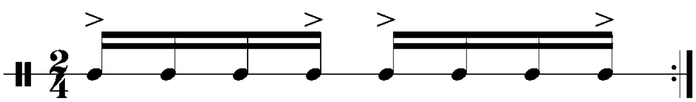
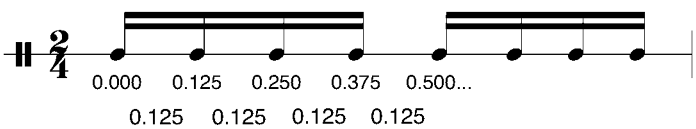
Figure 3



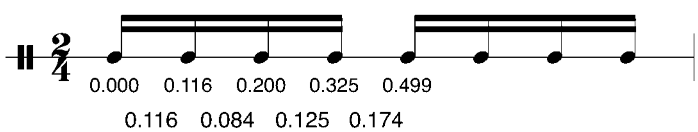
During the recording a metronome was set to 120 bpm, so if we divide 120 by 60 (one minute) we get two beats for every second. This means that the interval between every consecutive sixteenth note is always 0.125 sec (or 125 millisecond). See Figure 4.

Figure 4



This musical notation could be written for a rudimental drum line but not for samba. The rhythm has no *swing* and therefore could not precisely represent an actual samba rhythm. It could, however, be interpreted yet limited to those with vast exposure to that *feel*. Figure 5 shows the interval between each sixteenth note as played by the tamborim rhythm.

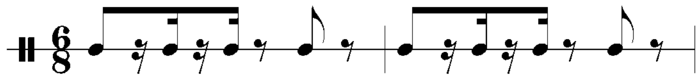
Figure 5



The results demonstrate that although customarily the notation for samba rhythm presents even sixteenth notes, the actual performance is quite different. The second and fourth strokes are significantly modified to create a syncopation that pushes the beginning of the third and fourth notes before the beat. The second note is shortened to approximately 2/3 of the standard length while the fourth is dilated to about 4/3 to round out the measure and to ensure that the first note of the next measure is on the downbeat.

We propose a notational scheme that approximates this rhythm by shifting from 2/4 to 6/8 time with the tempo set at a dotted-half equal to 120 (or, equivalently, a quarter note equal to 180). See Figure 6.

Figure 6



As a test of the proposed notation, the score was coded in the composition softwares Finale and Sibelius and played. The rhythm simulated a very credible samba rhythm. Therefore, the authors offer this preceding notation as a facsimile of an actual performance that is based on objective measurement of a traditional performance.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the encouragement and many helpful discussions with Professor Chris Deane of the UNT School of Music.

About the computer-generated audio sample:
Software synthesizer: Kontakt Player
Sound sample: GM Drums

Performance configuration:
Style: Meccanico
Rubato: Meccanico
Rhythmic feel: Straight
Reverb: Small room

Dr. Sam Matteson is a professor of physics at the University of North Texas, where among his other academic responsibilities he teaches musical acoustics to undergraduate students majoring in music, radio, TV, and film, and the speech and hearing sciences. Among his research interests he includes the acoustics of musical performance. He currently serves as the Interim Chair of the Department of Speech and Hearing Sciences.

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