SUBIR LA LLAMADA: NEGOTIATING TEMPO AND DYNAMICS IN AFRO–URUGUAYAN CANDOMBE DRUMMING

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ABSTRACT

The leader–follower relationship among performers is an important aspect in the studies of interpersonal entrainment in the context of musical performance, specially when analysing the role of leadership in instances of changing tempo and/or dynamics. This research focuses on Uruguayan Candombe, a rich drumming tradition deeply rooted in the Afro–Atlantic culture. The purpose of this paper is to analyse the mechanisms by which Candombe drummers may coordinate and synchronize changes in tempo and dynamics during the performance, specifically at the process called *"subir la llamada"*. Of special interest is the analysis of the cues given by the drummer that leads the rest of the group in the process. Taking one particular recording by three expert Candombe drummers as case study, several computational tools were applied to extract features relevant to the analysis from the audio and video signals.

1. INTRODUCTION

The study of interpersonal entrainment in the context of musical performance is an area of research that has received increased attention in recent times. Its aim is to develop a better understanding of the ways in which groups of musicians coordinate their behaviour during performance (Clayton, 2012). An important aspect is the analysis of the leader–follower relationship among musicians, specially in instances of changing tempo and/or dynamics.

This research was carried out in the context of the Interpersonal Entrainment in Music Performance project (IEMP), [1] and its purpose is to analyse the mechanisms by which Candombe drummers coordinate and synchronize changes in tempo and dynamics during the performance, specifically at the process called *"subir la llamada"*. Of special interest is the analysis of the cues given by the drummer that leads the rest of the group in the process.

The research is based on a case study, analysing a specific performance with the aid of a set of computational tools. The chosen performance was taken as a complete musical statement by three individual performers, underlining at the same time idiomatic features commonly found in the corpus. The tools used are described in Section 4, and were applied to extract features relevant to the analysis from the audio and video signals (see Figure 4).

Thus, this study departs from the corpus analysis approach very common in computational musicology when dealing with non–Western traditional music, based on the statistical analysis of large amounts of data.

[1] https://musicscience.net/projects/iemp/

2. MUSICAL BACKGROUND

Deeply rooted in the Afro–Atlantic culture, Uruguayan Candombe drumming is internationally less known than other Latin American musics of African origin, such as Afro–Cuban or Afro–Brazilian. It possesses however a considerable rhythmic wealth and deserves wider recognition. Its most important and representative manifestation is the *llamada de tambores*, a drum–call parade of a group of drummers (typically between 20 and 60) marching on the street playing the characteristic Candombe rhythm, also called *ritmo de llamada*.

Like in other musics of the Afro–Atlantic tradition, the rhythm of Candombe is clave–based, with a cycle of four beats subdivided in sixteen pulses. The rhythm is the result of the interaction of the patterns of three drums of different size and pitch, called *chico*, *repique* and *piano*. The drum–head is hit with one hand bare and the other holding a stick that is also used to hit the shell when playing the *clave* or *madera* pattern (Figure 5). This timeline pattern is played by all the drums as an introduction to and preparation for the *llamada* rhythm; during the *llamada*, it may be played only by the *repiques* in between phrases (Jure, 2017).

Tempos in Candombe may vary from ca. 100 bpm for a slow *llamada* to around 150 bpm for very fast performances. The most characteristic tempos, however, are in the range of ca. 130 to 136 bpm. It is relatively common to begin the *llamada* at a slower tempo and then increase the speed to reach a typical tempo. After that, minor fluctuations are idiomatic (Figure 6). Essential to this practice is the concept of *"subir* ("raise") *la llamada"*, a term shared and understood by all the members of the community, although not formally defined. This process is primarily associated with an acceleration in tempo, but also involves an increase in dynamics and the use of certain patterns perceived as conveying more energy. The instance of one of the performers giving the cue to begin this process is referred to as *"llamar* ("call") *a subir"*.

2.1 The three drums and their rhythmic patterns

The three drums have different functions in the rhythm and specific patterns associated with their respective registers. The small, high–pitched *chico* drum is the timekeeper, establishing the pulse by repeating a simple one–beat pattern throughout the whole performance (*chico de dos* or *chico liso*). The only possible variant is playing an alternate pattern in sections with a slower tempo (*chico de tres* or *chico* *repicado*) (Figure 1). [2]

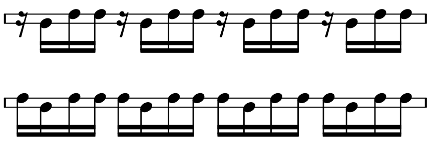

Figure 1: Standard *chico* pattern (top) and a common variant used in slower tempos.

The middle–sized *repique* drum, on the other hand, is regarded as a soloist and improviser, and has the greatest degree of variability among the three drums. During performance, a *repique* player typically interposes cycles of *madera* pattern in between *repique* phrases. These can be characterized by having a higher degree of syncopation and rhythmic and technical complexity. The *repique* has, however, a primary pattern (*repique básico* or *repique corrido*), that may constitute a significant portion of the performance of a *repique* during the *llamada* (Jure, 2013). The short excerpt transcribed in Figure 2 displays these three behaviours.

The piano drum, the largest and lowest sounding of the three drums, has two different functions. The primary one (*piano base*) is to delineate the timeline with characteristic one–cycle patterns. There are many variants, that depend on both the style of each neighbourhood and on the individual style of the performer. But the piano drum can occasionally interpose more ornamented *repique*–like patterns (*piano repicado*), typically one or sometimes two cycles long (Rocamora et al., 2014).

Figure 3 shows the two main *base* and *repicado* patterns found in this recording. They are notated in their basic configuration; [3] during actual performance several subtle variants are introduced by means of added strokes and ghost notes (see also Figure 8).

3. CASE STUDY

The recording taken as a case study in this work is part of the audio–visual dataset of Candombe performances presented in (Rocamora et al., 2015). It features three expert drummers of the same generation, members of families of long–standing tradition in the community of barrio Palermo (Ansina): Héctor Manuel Suárez (b. 1968), Luis Giménez (b. 1969), and Sergio Ortuño (b. 1966). The three are known as accomplished players of the three types of drum, but in this particular take they played *repique*, *chico* and *piano*, respectively (see Figure 5).

The performance was recorded using a multi–track audio system and filmed with a multiple–camera video set–up. The audio set–up provided a stereophonic recording of the ensemble and separate audio channels of each drum—yielding clean direct sound from a given drum, with almost no interference from the others. Therefore, the separate audio channels were used for automatically extracting information of each drum independently. As for the video, only the wide shot of the ensemble was used in this work.

4. INFORMATION EXTRACTION

Some computational methods for information extraction are applied to the audio–visual record of the performance (see Figure 4), for capturing and representing the evolution over time of the most relevant aspects noted above, namely tempo, dynamics and rhythmic patterns. For the analysis of dynamics only the *chico* drum is considered, since—given that it always repeats the same one–beat pattern—it allows for a consistent and comparable estimation throughout the whole performance. Two different kinds of information are extracted for this purpose: the root mean square (RMS) value of the audio waveform of the separate track, and the amplitude of the trajectory of the left hand of the performer obtained from the video. In addition, an onset–based asynchrony analysis is carried out, for providing information on interpersonal entrainment and leadership.

4.1 Tempo curve

The evolution of the tempo is computed as the inverse of the difference between two adjacent downbeats (first beat of the four–beat cycle) and expressed in beats per minute (bpm). The downbeats were automatically extracted by using *BayesBeat* (Krebs et al., 2013) trained with the dataset released in (Nunes et al., 2015). The extraction of downbeats was very reliable, yielding an F-measure of 100% when compared to manual annotations using the standard ± 70 ms tolerance, as in (Nunes et al., 2015). The resulting tempo curve is depicted in the second plot of Figure 6.

4.2 Dynamics

The root mean square (RMS) of the audio waveform of the *chico* separate track was computed for consecutive signal frames (using a frame length of 1 second and a hop size of 0.5 seconds) and expressed in decibels. The third plot of Figure 6 shows the RMS values obtained (solid line).

The left hand of the *chico* performer exhibits a cyclic up–down movement in relation to the drum head, that corresponds to the hand stroke at the second subdivision of each beat (in both patterns, see Figure 1). A measure of the range of the trajectory of the left hand of the *chico* performer is considered as an indirect estimate of the dynamics of the performance. To do that, an existing computer vision system called *OpenPose* was applied, that detects human body, hand, and facial keypoints for multiple persons from single images (Cao et al., 2017). An example of the detections for one video frame can be seen in Figure 4.

The location of the left hand in each video frame is provided as an x–y point in pixels. Then, the locations are further processed using moving maximum and moving minimum filters to estimate the boundaries of the hand move-

[2] In all the examples, the lower line represents the hand and the upper line the stick, with an X representing the *madera* sound. Parenthesized notes are de–emphasized or ghosted.

[3] The technique of the *piano* drum is more complex and requires some additional symbols: a cross represents a muted note (the hand and/or stick rest on the drum–head after striking it), and a stem without note head means dampening the vibration with the palm without producing a sound. The triangular note head means palming the drum head with the fingers.

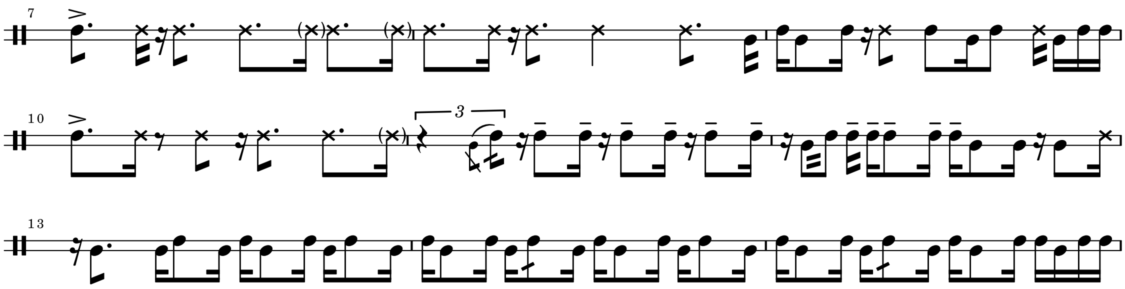

Figure 2: Transcription of mm. 7–15 of the *repique* solo in this performance, displaying the *madera* pattern, complex improvised phrases and the primary *repique* pattern at the end.

Figure 3: Rhythmic patterns of the *piano* drum in this performance. From top: *base 1*, *base 2*, *repicado 1* and *repicado 2*.

ment within a certain time interval. Finally, the difference between the estimated boundaries is considered as the extent of the trajectory over time. The result of this procedure is represented in the third plot of Figure 6 (dashed lined). It is worth noting that, not surprisingly, the RMS values and the hand motion signal show roughly a similar behaviour. [4]

4.3 Rhythmic pattern analysis

The analysis of rhythmic patterns is based on the spectral flux, a feature extracted from the audio signal that captures changes in the energy content in different frequency bands. The separate audio track of each drum is processed to conduct two different type of analysis: 1) the detection of *madera* rhythm cycles (Rocamora & Biscainho, 2015; Jure & Rocamora, 2017), and 2) the extraction of a feature map of rhythmic patterns (Rocamora et al., 2014).

The spectral flux feature is computed through the Short–Time Fourier Transform of the signal mapped to the MEL scale for sequential 40 ms duration windows in hops of 10 ms. The resulting sequences are time–differentiated and half–wave rectified. The spectral feature is summed across all the MEL bands for onset detection, whereas the first MEL bands (< 1500 Hz) are used for sound classification.

Onset detection is based on a combination of a fixed and an adaptive threshold, as in (Böck et al., 2012). A Support Vector Machine classifier trained on isolated sounds is used to detect *madera* sounds. The proportion of onsets classified as *madera* within a rhythm cycle is used to detect *clave* patterns (Rocamora & Biscainho, 2015).

Then, the spectral feature summed across all the MEL bands is amplitude–normalized and time–quantized to the 16–subdivision grid using manually annotated beats and downbeats. A representation in the form of a map of cycle–length rhythmic patterns is straightforwardly obtained by building a matrix whose columns are consecutive feature vectors. Figure 8 depicts the map obtained for the *piano* drum track, where the horizontal axis corresponds to the cycle index and the vertical axis is the subdivision index. The columns of the map virtually correspond to each of the cycle–length rhythmic patterns performed by the *piano* drum along the whole recording. To aid the analysis of their differences and similarities, the rhythmic patterns are clustered using the K–means algorithm and the Euclidean distance, the number of cluster specified as an input parameter. The clusters obtained for the *piano* drum—shown with different colors in Figure 8—match the characteristic rhythmic patterns actually performed. The centroids of the clusters are also depicted in Figure 8 for reference.

A simplified schematic representation of the rhythmic patterns obtained for each drum is provided in the top plot of Figure 6, and will be analysed in Section 5.

4.4 Asynchrony between ensemble parts

An analysis of the asynchrony between onsets by different ensemble parts in the same metric position was carried out, following (Polak et al., 2016; Rocamora et al., 2017). Given the tempo changes of the performance, the onsets timing data was normalized to the four–beat rhythm cycle. To do that, the annotated downbeats were used as an initial reference, which was further refined by estimating downbeats positions as the average of the onsets of the different drums at the beginning of each rhythm cycle. Then, an aggregated histogram of all the onsets was computed, heuristic boundaries were defined between metric positions, and each onset was assigned to its corresponding metric bin. A virtual reference for each subdivision was obtained as the mean of all onsets within each metric bin.

Signed asynchronies were computed for each onset of each drum relative to the virtual reference subdivision. The values of mean and standard deviation of the signed asynchronies, computed for windows of ten consecutive rhythm cycles, are schematically depicted at the bottom of Figure 6.

[4] Pearson correlation coefficient: $r(342) = 0.56, p < 0.001$.

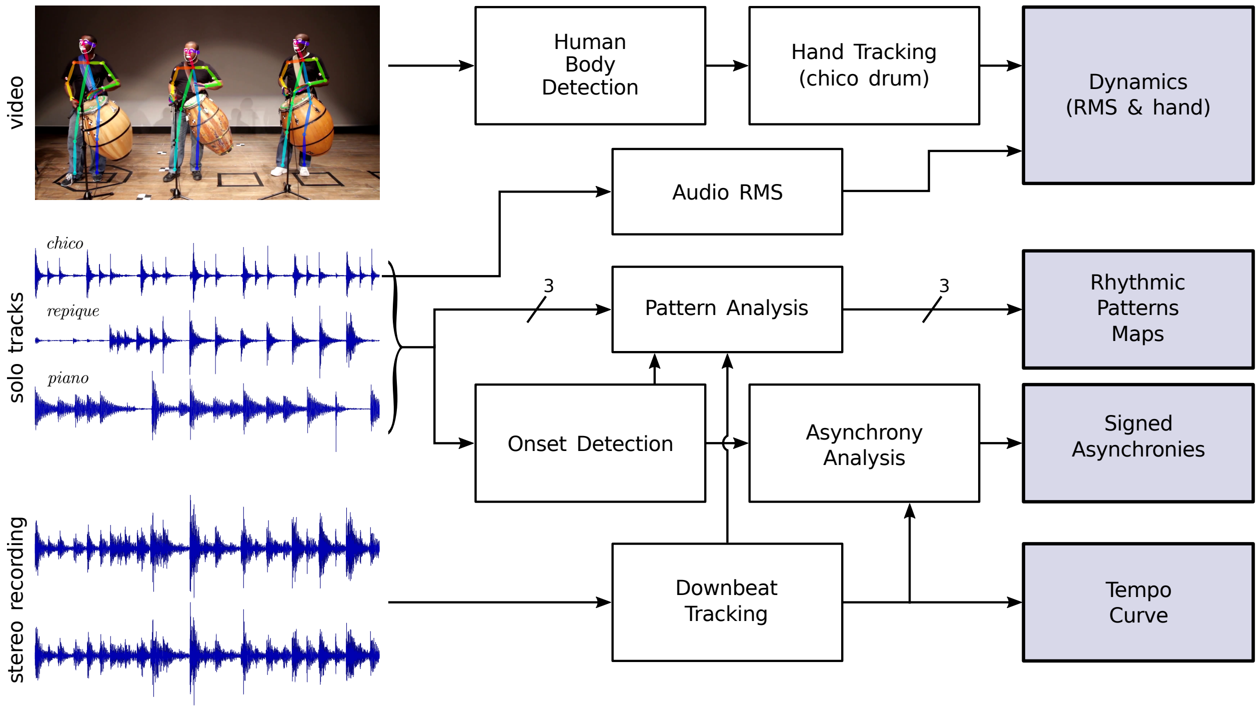

Figure 4: Block diagram of the computational tools applied and the information obtained.

Figure 5: Left to right: Héctor Manuel Suárez, *repique*, Luis Giménez, *chico*, Sergio Ortuño, *piano*.

Despite minor differences, the profile of the averaged asynchronies is similar along the whole performance, showing that the *repique* tends to play before the other two drums. The mean asynchronies obtained for each drum are below 2% of the normalized local beat duration, which corresponds to mean asynchronies in the range 8.2 and 12 ms, depending on the tempo value.

Figure 7 provides a detailed representation of the location of the onsets for the rhythm cycles corresponding to the first tempo increase (8 to 13). Note that the obtained grid of virtual reference subdivisions is not isochronous.

5. ANALYSIS

The recording has a duration of ca. 2:45 min. and comprises 86 complete cycles, ending in the downbeat of cycle 87. After a short introduction (a tremolo of the *repique* and two cycles of *madera* followed by a *repicado* in the *piano*), the *llamada* rhythm begins in the fourth cycle. The tempo curve shows an initial tempo that can be considered slow for Candombe (ca. 105–106), but—in a paradigmatic example of *subida*—there is a dramatic increase in tempo beginning at around m. 9–10, reaching a more typical tempo of ca. 128–130 at m. 15, and another (minor) increase around m. 22. This first section of the performance (ca. 50 seconds) was analysed with some detail, revealing some relevant aspects:

a) there is a strong but not linear correspondence between the tempo curve and dynamics of the *chico* drum, with increments in sound level and trajectory related with the increases in tempo (Figure 6, mm. 10–20);

b) the first *subida* is led by the *piano* drum by means of microrhythmical displacements of the notes. While the average asynchrony between the three drums remains approximately constant throughout the whole performance (Figure 6, bottom), Ortuño plays systematically ahead of the *chico* certain groups of notes in mm. 9–11 (Figure 7, compare with mm. 8 and 12–13);

c) the rhythm patterns play a fundamental role: the *piano* calls to raise the rhythm by playing ahead the notes located in specific places in the rhythmic cycle, the *repique* reinforces the raise by playing *repicado corrido*, and the *chico* switches from *chico de tres* to *chico de dos* when the new tempo is reached;

d) the second *subida* is essentially pattern–based: it is led by the *repique* by playing *repicado corrido* in m. 21, and the *piano* immediately responds by switching from the ornamented first base pattern to the “straighter” second base in m. 22 (Figure 3). The *chico* drum also reacts with a local increment in dynamics. Although quantitatively small, this second raise is perceived as a significant

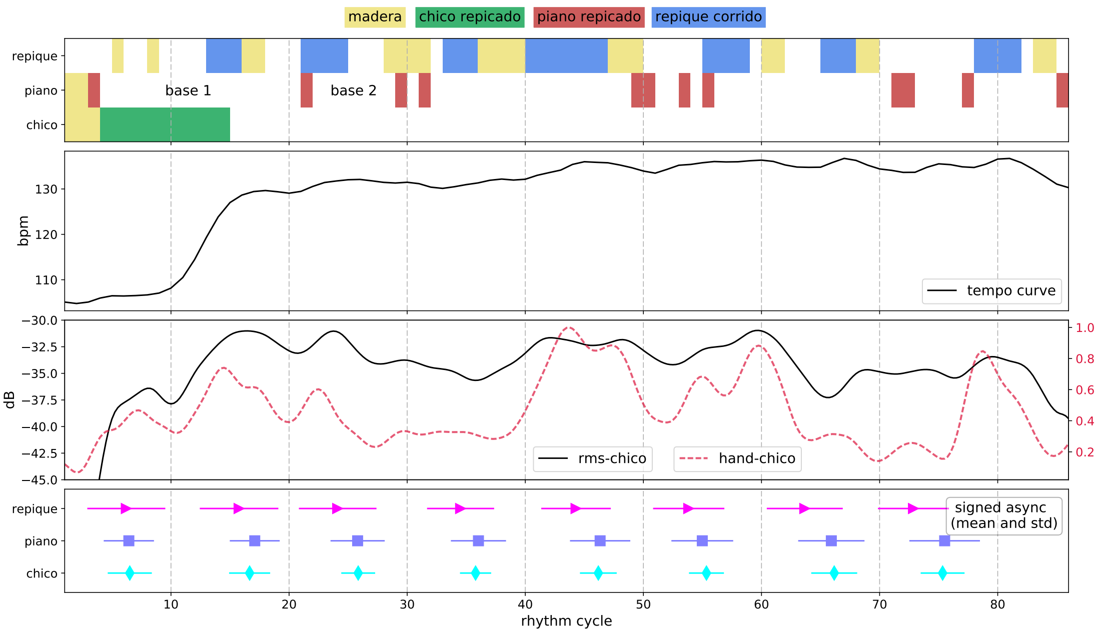

Figure 6: From top: main patterns of the three drums during the performance; tempo curve in bpm; dynamics curves of the *chico* (RMS and trajectory of the hand); asynchrony between the three drums in 10–cycle windows.

increase in energy, due to the patterns involved.

6. DISCUSSION AND FUTURE WORK

In this work, a particular Candombe performance was analysed with the aim to study the processes by which the players negotiate tempo and dynamics. Several computational tools were applied to the audio–visual record of the performance and succeeded in providing relevant information for the analysis.

Three phenomena were found to be involved in the process of *"subir la llamada"*: an increase in tempo (either moving from a slower initial tempo to a faster tempo, or a local *accelerando*); an increase in dynamics, measurable both in levels of sound energy and in the extent of the hand trajectory; the use of certain patterns considered to have a more propulsive rhythm: the *repicado básico* (as opposed to more complex figurations), the *chico liso* (as opposed to *chico repicado*) and a straight *llamada piano base* (as opposed to more ornamented *base* patterns).

With respect to the means by which one player leads the process (*"llama a subir"*), also three types of cues were found. As was expected, microtiming played an important role (arguably the most important), with the drum leading the process playing "ahead" to "push" the rhythm. Dynamics was also a factor (playing louder to signal an increase in energy), as well as the use of specific rhythmic patterns recognized as "callers" (*llamadores*).

In future work, the analysis of the facial key points provided by the computer vision system could be addressed, in order to extract further information on the interaction between musicians. Another relevant research strand to develop is the automatic detection of the information governing the mechanisms of coordination and synchronization, such as small variations in onset asynchrony, so as to be able to predict the changes in tempo and dynamics.

7. ACKNOWLEDGEMENTS

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Software tools were implemented in Python, using Scipy, Numpy, Matplotlib and Scikit-learn libraries. Music examples were typeset using LilyPond.

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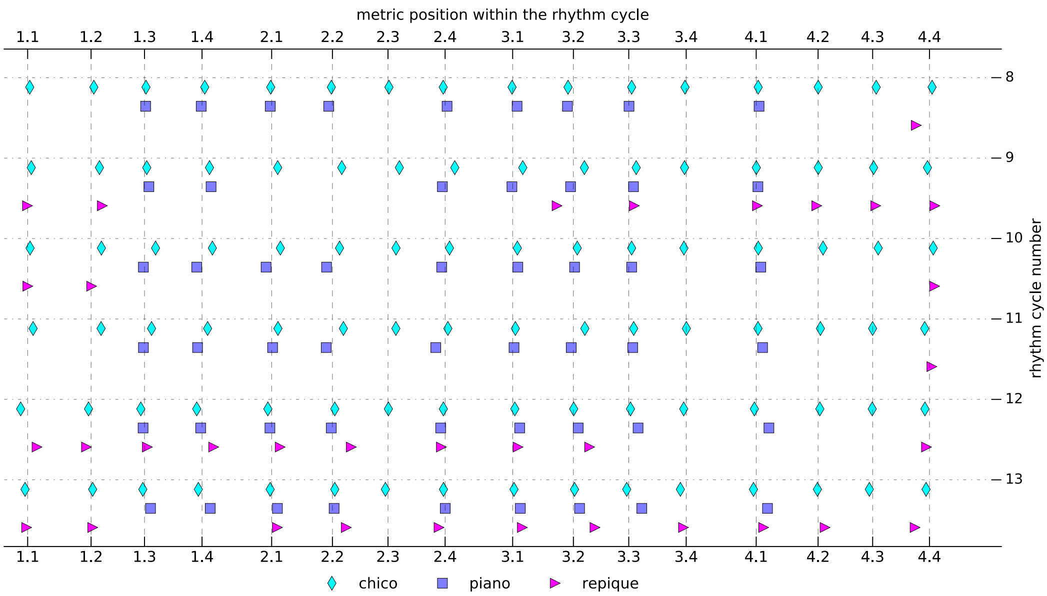

Figure 7: Normalized location of the onsets of the three drums for cycles 8 to 13.

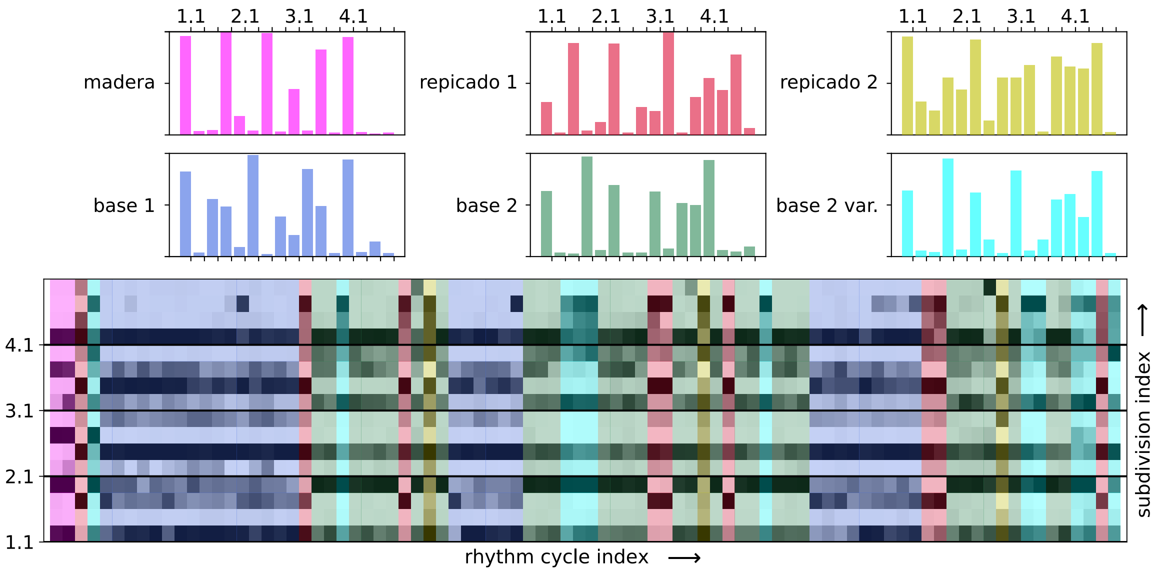

Figure 8: Analysis of the rhythmic patterns of the *piano* drum.

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