Digitizing the Txalaparta: Computer-Based Study of a Traditional Practice

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Abstract: This article describes a software implementation dealing with the ancient Basque musical tradition of the txalaparta. The research is different from earlier studies of the txalaparta in that, by digitizing the instrument and its performance rules, we have had to formalize and make explicit conventions that hitherto have been tacit knowledge of improvisational practice. Analysis through software development is an unusual case of musicological analysis as it demands clarity and precision, and often requires multidisciplinary approaches to understand the studied subject. We have developed software in order to analyze and understand a practice that has received little musicological analysis. By expounding musical patterns and performers' behaviors that have hitherto been difficult to analyze, we reveal the social and cultural aspects of performance practice.

The txalaparta is a two-performer instrument and the software produces txalaparta rhythms and plays along with a human player, while learning and adapting to the player's style. The system helps novices to explore the rules of the txalaparta and more-experienced performers to approach the instrument from a new perspective. In this research we have applied a user-centered approach, where feedback from players using the digital txalaparta was collected. This feedback allowed us to approach the reflective vision of txalaparta players and their thoughts on the results of our research.

The Txalaparta

The txalaparta (pronounced [tʃa'lapaɾta] CHA-la-par-ta) constitutes a percussion tradition that originates from the rural areas of the Basque Country. The instrument belongs to the category of struck idiophones and consists of thick planks of wood placed horizontally on two trestles, and beat vertically with heavy wooden batons. Other materials, such as metal, stone, or plastics, have also been used but wood is most common. The txalaparta is typically played as a solo instrument by at least two performers alternating their strokes in a call-and-response pattern, generally improvised, to construct a rhythm. This particular setup, shown in Figure 1, leads to a unique and close interaction between the players. Indeed, the txalaparta is one of few instruments in the world that cannot be played by only one performer: the collaborative play is its nature. The txalaparta was an obscure tradition that was not integrated into the mainstream tradition of Basque folk music until the last few decades. This is perhaps because of its peculiar rhythm, improvisational nature, and exotic character. Yet it is precisely this unique character of the txalaparta that has attracted the interest of avant-garde artists and experimental musicians since the 1960s. In this article, we will first describe the musical practice of the txalaparta and present a contextual history of its role in contemporary culture. We will then demonstrate our work in formalizing its rules as part of the creation of a software-based txalaparta.

Very little is known about txalaparta practice before the 20th century, although various theories exist regarding its origins (Goiri 1994, pp. 43, 64; Aguirre 2004; Beltran 2004, p. 124). Some theories link the txalaparta to the festivities around the harvesting of apples for cider production. Others suggest that the txalaparta was used to communicate between mountain farms. The first historical reference to the txalaparta appears in a book about cider production in the Basque Country (Aguirre 1882, p. 129), although there are previous mentions of the tobera (a metal variant of the txalaparta), the earliest found in

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Figure 1. The Ugarte Brothers playing a txalaparta. (Photo by Xabier Eskisabel. Creative Commons BY-SA.)

a legal document from 1688 (Lekuona 1920, p. 52). In the mid-1960s the practice of txalaparta playing had almost disappeared and was unknown to most people in the Basque Country. Only two pairs of players would play the txalaparta publicly, although current research into txalaparta practice suggests that more people played in private. The txalaparta was known, however, by some anthropologists and by people in the cultural and arts sectors, who were becoming increasingly concerned with its disappearance, and who sought to bring the tradition to the attention of young artists and musicians.

During the late 1960s, as in many other places in the world, a strong popular cultural movement began to grow in the Basque Country. This was an important movement, because during the Spanish Civil War (1936–1939), and in the cultural repression that succeeded it with the Franco dictatorship, many Basque artists and intellectuals had either been killed or left the country. The new artists and musicians began to be interested in traditional oral literature, dance, and music, with the purpose of generating a new culture based on a traditional lineage, but one that would fulfill the needs of modern society at the same time it elaborated on ideas from avant-garde modernity. This connection between the popular and the avant-garde is a global process, described by Mark Fisher (2014, p. 33), who calls it "popular modernism." It implies a dissemination and reformulation by the popular culture of ideas and concepts explored by modern art, music, and literature. In the Basque Country this movement brought with it a strong revolutionary and antidictatorial ideology. The txalaparta became a perfect vehicle for this context, as it was unknown, and thus free from the weight of tradition, while

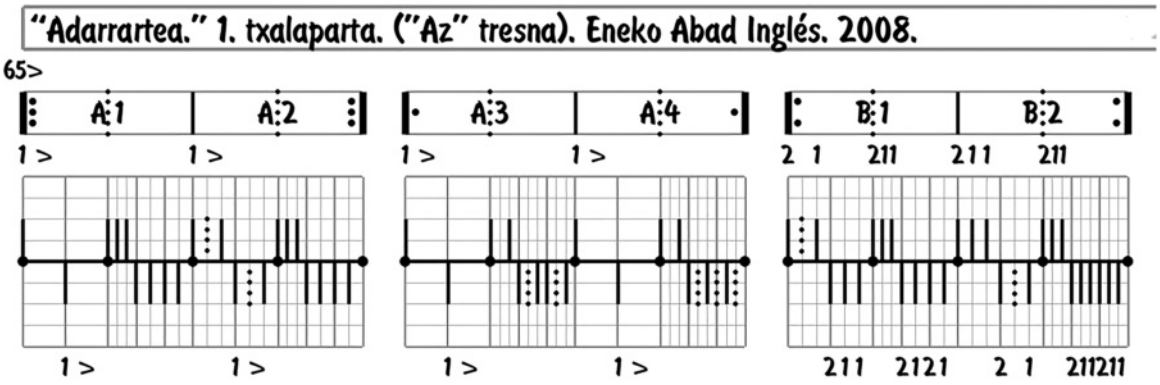
being uniquely distinct from other local musical traditions. New players began to eagerly study the art of txalaparta from the two pairs of players still active, and so the practice moved from its traditional rural environment to the one of art, cultural activism, national identity, and political struggle.

The txalaparta is therefore a fascinating cultural manifestation in many respects, relating not only to Basque national identity, the revolutionary period of the 1960s, and folk music, but also, interestingly, within the context of contemporary experimental music. The recovery of txalaparta during the 1960s, and its evolution since then, is an interesting process for two key reasons. First, like other traditional music, the txalaparta has custom and unique sets of formal rules (among other characteristics, such as the use of collective improvisation, exploration of timbre, use of irregular rhythms, virtuosic performance, etc.) that have proved inspiring to practitioners of experimental music. Second, the process of its recovery happened under a strong influence of avant-garde artists, such as Jorge Oteiza, who played a significant cultural role in the Basque Country during the 1960s and 1970s. Oteiza developed an aesthetic theory, arguing that sociopolitical reality could be transformed using artistic activities. Influenced by the avant-garde movements of lettrist and concrete poetry, another prominent artist during that time, José Antonio Artze, together with his brother Jesús, conceived of the txalaparta as poetical rhythm, almost phonetic, in an attempt to contribute to the construction of a Basque cultural identity, joining tradition with contemporary experimentation in the process. This combination led to an ancient tradition meeting radical modernity, receiving interest from groups outside the community of musical practitioners, to the point that nowadays txalaparta is one of the most well-known and popular musical instruments in the Basque Country with thousands of amateur players, and it has become an icon symbolizing Basque culture.

What is known about the old style of playing the txalaparta before the 1960s (known as txalaparta *zaharra*) is based on the descriptions and recordings of the very few players left in the early 1960s when the txalaparta was recovered. The players take clearly defined roles in the call-and-response improvisatory process where the bar is split into two, roughly equal parts, one for each player. The first role, called *txakun*, maintains a rhythm of two strokes with a fluctuating pulse. The second role, *errena*, is freer and is able to response with one or two strokes as well as resting, as seen at the beginning of Video 1. (Video examples are available at https://www.mitpressjournals.org/doi/suppl/10.1162/COMJ_a_00522). Performances usually start with a medium tempo that increases, reaching a climax in which the rhythm reaches a static stage lasting a few seconds, after which the performance stops abruptly. The players do not seek to maintain a clear metric pulse or regular subdivisions, and this results in an organic rhythmical structure. The old instrument consists of a single plank about two meters in length, sometimes longer, and players will search for timbral variations in the plank with their strokes.

Nowadays, txalaparta players usually study and practice both the old and the new styles of playing and the old style is still alive. The new styles of txalaparta that developed after the 1960s are usually known as txalaparta *berria* (new). Here both players are free to play without any restrictions, and they can play in their part of the bar with up to four strokes (occasionally more), as well as resting. Free-form responses are also allowed but are less common (see beginning of Video 2). Any type of metrical structure can be used and interpreters can play with the time gap between the strokes, as well as with the amplitude and timbre of the strokes. In addition to these innovations, a wide range of tempi can be used, and it is common to change tempo several times within the same performance. These performance sessions are usually longer than the traditional ones and often have very strong changes in dynamics (again, see Video 2). The new txalaparta emphasizes virtuosic playing, which means that performers must listen carefully to each other to adapt and build a meaningful improvised development of the session. Performers are now more interested in the timbral palette provided by different materials, so different types of woods and even other materials, such as stone, glass, or plastics, have come into use. Although performers

Figure 2. Detail of a txalaparta score by Eneko Abad.



of the new txalaparta do not try to break away from the traditional txalaparta, these minor changes in performance and instrumental nature are quite noticeable, considering how minimalist this musical style is. The old txalaparta rhythm was additive, where parts progressed with a fluid sense of time. In contrast, current txalaparta practices tends to use divisive rhythms, where parts are like musical bars in a set tempo, although this is not always the case. It is also important to note that the old players would play txalaparta only a few days a year, typically during festivities, while some of the new players practice every day and perform publicly dozens of times in a year year.

In the mid-to-late 1990s the situation changed further with the development of the pitched txalaparta process, defined by Argibel Euba (2004) as *xylophonization*. In addition to pitched wooden planks, metrical structures (e.g., pulse, subdivisions, and rhythmic changes) have also become increasingly standardized and thus more "aligned" with other musical practices, and so better suited to the concerns of typical musicological analysis. The popularization in the last decade of using the txalaparta to play melodies has, in some cases, weakened the complex interrelation between players to the point that sometimes it is only the practice of interlocking beats that remains from the old performance style (Escribano 2012, p. 225). These changes in performance and organology have resulted in a style of playing where the txalaparta has become a form of marimba, as the planks and sticks shorten to accommodate the requirements of new players who search for tonality.

Related to these changes, a form of musical notation has emerged for txalaparta playing. Although some composers have written pieces for the txalaparta using notation (e.g., Eneko Abad and Sergio Lamuedra), most players still prefer to improvise. This might have to do with the intense focus on speed and player communication that often characterizes modern performance practice. The musical notation such as the one shown in Figure 2 is still useful as descriptive notation preserving performer style and knowledge, as well as for students of the txalaparta. In txalaparta scores time is mapped to space (reading left to right), with vertical lines representing strokes, dotted vertical lines representing rests, and numbers above and below showing which plank corresponds to which stroke. The long horizontal line separates the strokes assigned to the first player (above the line) and those to the second one (below the line). Although most scores usually follow those conventions, there is not a fully standardized way to write scores and there are differences between players. We followed some of those conventions while designing visualization aids in our software, as we describe later. (For further details on txalaparta scores cf. Hurtado and Magnusson 2016.)

The above developments have raised concerns about some of the txalaparta's original characteristics being lost, to the point that some players claim that developments such as xylophonization cannot

be described as txalaparta. This is a process that has already happened to other musical traditions, when faced with notated music:

> The petrifying effect of European classical music on those things it touches—jazz, many folk musics, and all popular musics have suffered grievously in their contact with it—made the prospect of finding improvisation there pretty remote (Bailey 1993, p. 19).

The current use of scores and the practice of tuning the planks are also controversial, reminding us of the criticism in the late 1980s, claiming that the introduction of regular metrics was changing the practice too much. Despite this tendency toward metrical and tonal standardization, however, the txalaparta remains a heterogeneous practice with no standard way of playing, building the instrument, teaching, or writing scores.

Txalaparta, Experimental Music, and the Avant-Garde: On Processes and Rules

Since the 1950s, many composers have eagerly explored the idea of the "open work" (Eco 1989), rejecting the idea of a fixed determined composition and instead applying various techniques to produce different results every time the music is performed. Techniques such as the use of indeterminacy, formal processes, and improvisation have been key elements in contemporary music. Composers such as Cornelius Cardew, La Monte Young, Christian Wolff, and Earl Brown implemented these types of strategies, but it is perhaps Terry Riley's popular *In C* (1964) that most perfectly embodies these characteristics. In his piece, Riley proposes a situation where, based on predefined musical material and by following a set of rules through collective improvisation, a structure emerges where the relationships and interactions between performers are crucial to the development of the piece. Riley defines the situation and the process as parts of the composition that yield potentially infinite versions of the piece, which is one of the main characteristics of generative processes. In the context of this article, we could define the following as the main characteristics of generative music:

1. Those works are process based.
2. The process can be described as a set of instructions.
3. The process leads to different results each time it runs.
4. The process can be autonomous or semiautonomous.
5. Those works are not only computer based or digital.

The renewed interest in the txalaparta in the 1960s was concurrent with globally emerging compositional trends in experimental music that emphasized process-based and nonlinear compositions, which sometimes embraced improvisation and the use of semi-open rules. This led to compositions that produce different results every time the music is interpreted, similar to the old style of txalaparta play (and most of the new style). It was at the 1972 Encounters Festival in Pamplona, organized by the composer Luis De Pablo, that the relationship between the txalaparta and international experimental music was consolidated. Artists and musicians from all over the world met at that multidisciplinary encounter filled with exhibitions, concerts, performances, and film screenings. The Artze brothers played at the festival in front of an audience formed by artists and musicians, including John Cage, Steve Reich, and Walter Marchetti, among many others. Cage was fascinated by the rhythmical structures of the txalaparta and stated that it was the best work performed at the Encounters Festival:

> Ah, Txalaparta? Ah, the music with the sticks with the natural rhythm of the gallop. . . I just listened to it and it is absolutely delicious. I could listen to it for hours. It is a very flexible and malleable music (Jover and Amestoy 1972, translated from the Spanish by the authors).

Steve Reich also expressed his surprise in discovering such rhythms in a Western musical tradition, and he wrote enthusiastically about the concert in his notebook (Reich 1972; Hurtado 2015, pp. 109, 232), spending some time studying the txalaparta in the ensuing days.

> Completely hocketing only two people—[the] player said more than two would fill up all the spaces making melodic patterns. The only objection I would make to what I heard is that it lacked a system, a process and so the technique is fantastic, the sound is fantastic but, perhaps because it was improvised and not part of fixed tradition, it lacked a certain depth (Reich 1972).

In 2009, Reich acknowledged (in an interview with Argibel Euba as part of the latter's PhD research) the influence this event had on his composition *Clapping*, written that summer, and the subsequent *Music for Pieces of Wood*, from 1973.

The txalaparta seemed to fit well to this new musical landscape that emphasized rules, improvisation, collaboration, and freedom from standard notation—eagerly incorporating elements from outside the Western musical tradition. The unpretentious and low-level approach, the humble origins, and the obscurity of the practice seemed to attract the international composers and theoreticians. Furthermore, some commentators and practitioners of txalaparta claim that the txalaparta is not the physical instrument itself, but the rhythm and the rules that are applied (Beltran 1988, p. 198; Escribano 2012, p. 4). Like many contemporary musical compositions, txalaparta performances can be described as a process defined by a series of instructions that the interpreters use as guideline to improvise rhythms. This distinction between the txalaparta rules and the physical instrument was fortunate for this current research, as designing a digital version of the txalaparta engages primarily with its rules as opposed to the material from which it is constructed.

Digitizing the Txalaparta: Context

Although there has been much interest in the txalaparta since the 1960s, formal musicological analysis of the practice has not been conducted until now, probably because of its nature as an improvisational practice with no common repertoire, recordings, or written documents to study. Another reason for the lack of musicological work might be the fact that the music was unpitched, consisting of rhythm only, it has frequently been played by musicians with no formal training, and often performed outside contexts that we would define as being musical. Finally, we might explain the practice's exclusion from musicological study by considering that it may have been viewed as more of a game than a form of music by some musicologists—lacking performance contexts, a lineage of performers, and organological knowledge—and for that reason early ethnomusicology ignored the practice. This is now changing, and the txalaparta is increasingly gaining interest from the ethnomusicology research community.

Nowadays there are scholarly publications that introduce the practice (Leaf 2007), explore notational transcription (Euba 2004), perform acoustic and rhythmical studies of the instrument (Sánchez and Siguero 2000; Gambra 2008; Ralla 2014). Doctoral research has been conducted: there is an extensive anthropological thesis by Maria Escribano del Moral (2012), this article reports on the recent research conducted by the first author (Hurtado 2015), and a recent doctoral dissertation by Euba (2017) engages with the tradition from the perspective of ethnomusicology. Furthermore, Beñat Ralla Yusta is finishing his dissertation from the perspective of pedagogy (Ralla Forthcoming). There are also books by key practitioners working outside academia who attempt to trace the origins of the instrument and its history after the 1960s (e.g., Goiri 1994; Beltran 2004, 2009). This sums up most of the literature on the instrument.

There have been some attempts at producing software based on the txalaparta, and these projects are worth mentioning here. In the 1990s the Laboratorio de Tratamiento de Palabra y Música in Madrid developed software they called the Tecnotxalaparta, which was a command-line application capable of listening and responding to human players in real time. Input was through keystrokes on the computer's keyboard and the output was in the form of MIDI messages, sent to a sampler with txalaparta samples. This software was never released and is now "abandonware" (personal communication with Francisco Javier Sánchez González, 11 October

2014). In 2002, ixi audio released an application called Txalaparta, that had been developed by the first author. The interface consisted of a display in which two pairs of rectangles representing the sticks could be controlled and an on-going rhythm would be produced by the system (this application was never made publicly available and was only ever used by a limited number of musicians in the Basque Country). Ttakun was another application, developed in 2005, which worked as a sequencer aimed at creating compositions and exercises for the txalaparta (https://github.com/Soinuenea/ttakun). It provided dozens of exercises grouped by levels of difficulty. It could be used as an accompaniment by creating a sequence containing one player's part, after which the user would play a real txalaparta while the computer played back the sequence. Recently there have been some attempts to use touch interfaces to replicate the interface of the txalaparta. The Txalapartapp for iOS is the most sophisticated of these, where the user can play the planks on screen. It also has a mode where the user must follow the rhythm the app plays. The play is not generative in any way, however, consisting only of predefined looped sequences.

Although the software described above has all focused on the txalaparta in some way or another, none of it is generative or collaborative where the human performer plays with a listening machine. There are, of course, numerous projects along these lines: Some focus on *tal* music from North India (Wright and Wessel 1998); others on improvisation, such as The Continuator (Pachet 2002), which is one of the most relevant giving the objectives and the technology used; Haile (Weinberg, Driscoll, and Parry 2005); the Robotic Marimba Player (Weinberg and Driscoll 2007); ImprovGenerator (Kitane and Koike 2010); or Shimon (Hofman and Weinberg 2010). More recently we find projects focusing on traditional music from Ethiopia (Herremans et al. 2015). We have been fortunate to conduct this study in a well-defined, yet open practice, interacting with a closely-knit community of practitioners who have been interested in the research project from the start. In the following sections we will describe the Digital Txalaparta, its development, and community reception.

The Digital Txalaparta

An interesting problem presented itself to us: How can we represent a practice that itself is considerably undefined? And, what does it mean to move real-world practices into the digital domain?

Objectives, Research Questions, and Methodology

A key objective of the Digital Txalaparta was to understand and formalize the rules manifested in txalaparta playing, such that we could develop software applying those rules. The research questions can be grouped into three areas. First, we wanted to study the relationship between the txalaparta and avant-garde music: Why did the txalaparta catch the interest of artists and musicians in the 1960s and 1970s? Considering that these people were often pioneers in electronic music, we seek to understand the practice in this context. Second, we wanted to formalize the txalaparta rules and explore how the computer can help us to understand them from a new perspective: Is the txalaparta an instrument, a type of rhythm, or a set of rules? Is there anything unique in txalaparta practice compared to other improvised music? Can the rules of the txalaparta be described and translated into a digital algorithm? Finally, we were interested in reflecting on the reactions of the musicians who worked with our software, discussing with them the stylistic and organological changes the txalaparta has undergone, with the digital txalaparta as part of that process.

We applied methods from different disciplines such as sociology, ethnomusicology, software development, and human–computer interaction. We used semistructured interviews, observation, documentation research, user tests, casual talks, and online surveys. The relationships that we have established with key practitioners have continued, and we now work in a close collaboration with experienced txalaparta interpreters, some of whom have become intimately involved in the development of the software. We also created a survey sent to txalaparta players, the first ever on the txalaparta, which helped us to collect opinions about different aspects touched on this research.

Describing the Rules

Txalaparta performance can clearly be described as a highly rule-based activity, albeit one with a characteristically tacit nature. This suggests that the task of creating software for the txalaparta would require a strong explicit understanding of its nature and formalization of its rules (unless a machine-learning approach is taken, which was not our case at that point, mostly because we were particularly interested in trying to understand the link between the txalaparta and the rule-based compositions from 1960s experimental music). Here, therefore, the txalaparta appears slightly differently from many other percussion instruments, as the txalaparta is a manner of playing (with rules applied) as well as the physical instrument itself, as we have already pointed out.

A summary of the tacit rules we observed during our research of txalaparta performance will be described in the following. Note that this description covers only what we think is the more standard way of playing improvised txalaparta, and that there are styles of playing and performers who will not fit fully with this description.

1. Txalaparta improvisatory play is performed by two performers who split the bar into two roughly equal parts, each taken by one performer.
2. Although players are free, often one of them takes a leading role while the other one tends to follow. These roles can move between players during a performance, akin to a human conversation.
3. The performance typically presents a loose call-and-response structure, where the first performer plays a theme that is answered by the second player.
4. Within their part of the measure, performers can perform up to four strokes or a rest. Any combination of strokes is possible but, not two consecutive rests, as that would be understood as the end of play.
5. Within their part of the bar, players can position strokes tightly together to the point of stroking at the same time with both sticks, or spread them in time, but they rarely go over the other player's part of the bar (as seen in Videos 3 and 4).
6. Strong variations in dynamics can be applied both to the general structure of the play or to the individual strokes within a response.
7. Any plank can be struck (unless some kind of restriction has been agreed upon beforehand).
8. Performers can strike any part of each available plank but they tend to concentrate in the areas where planks vibrate more freely.
9. Although each response is unique, players often repeat a response for a few bars, introducing small differences each time they play it. They also sometimes come back to a previously played response or work out new variations of previously played responses.
10. Txalaparta performers are in constant negotiation to establish a consensus on the tempo, time distance between strokes and amplitude, while they tend to diverge playing with consensus, divergence, and copy in other options, such as the number of strokes in the responses and the planks they hit.
11. The length and global structure of the improvised play can be completely free, although most players often agree upon some kind of loose structure beforehand. For example: start slow, then speed, up then keep the tempo for two-three minutes while performing different rhythmical combinations, and finally transitioning to a faster tempo to end abruptly.

The Software

Our aim was to create software that would produce generative txalaparta rhythms and that could run on standard laptops without the use of expensive sound interfaces or sensors. The result was the Digital Txalaparta, software in two parts: The Autotxalaparta and the- Interactive Txalaparta. Both applications were developed using the SuperCollider programming language and produce sound by using real txalaparta samples. Users can record and introduce

into the application several strokes recorded from each plank in their txalaparta (we suggest recording strokes both with different amplitudes and from different locations on the plank). Up to 25 samples per plank can be used, as we divide each plank horizontally into five areas, with up to five strokes per area. Sounds can simply be copied manually into the samples folder following a naming convention, which is specified in the documentation, or they can be recorded using a small control panel we developed in SuperCollider and that automatically records, splits, normalizes, and saves the individual strokes to the appropriate folder with the correct naming. This system sometimes fails to detect and extract the strokes properly, however, and this is why recording and introducing them manually is currently the preferred option.

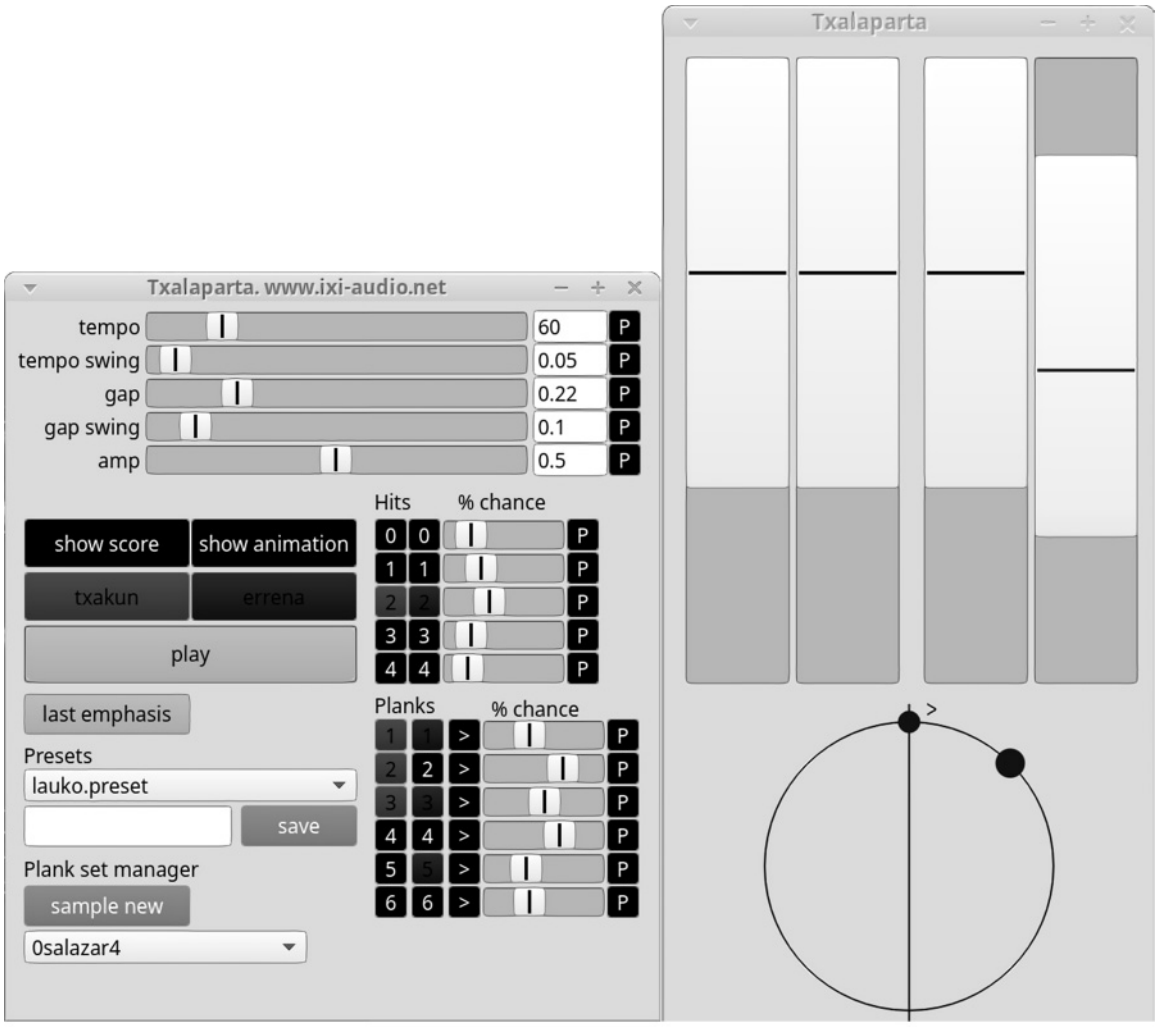
The Autotxalaparta

The Autotxalaparta (see Figure 3) is a semiautomatic generative software that emulates txalaparta performance. It generates both parts of the txalaparta rhythm, simulating the two players. Its development allowed us to better understand the options performers face when they play and the tacit rules that we have described. The GUI allows the user to control the main parameters of the rhythmic process. These parameters are tempo ("tempo" and "tempo swing" sliders), followed by the time distance between strokes within responses ("gap" and "gap swing" sliders). The "swing" parameters allow tempo and strokes to deviate slightly from the precise timing values given ("tempo swing" and "gap swing" sliders). This last option is an attempt to simulate swing as it occurs in live performance. Below the main sliders, we find controls to choose the number of strokes each of the players is allowed to perform within responses ("Hits" buttons). Near those controls we find sliders to adjust the chances for each of the number of strokes to occur ("Hits % chance" sliders). Right below we find controls to decide which planks are available to each performer ("Planks" buttons) and probabilities for each available plank to be struck ("Planks % chance" sliders). The Autotxalaparta can be set to only produce a single voice, enabling people to play the real txalaparta following the computer's output. Here the software plays in the first part of the bar and the human responds in the second part (cf. Video 5). Performers who tested this feature found it both intriguing and strange at the same time, as we will discuss in the section on "Evaluation."

The Interactive Txalaparta

We received valuable feedback and suggestions while demonstrating Autotxalaparta to experienced txalaparta players. This led to the development of the Interactive Txalaparta (see Figure 4), a new program that analyzes the human performer's play, using standard microphone and machine listening techniques, and producing the second part of the txalaparta rhythm, thus allowing a human to play txalaparta with the machine. We use several techniques to analyze the microphone input. When a human plays with the Interactive Txalaparta, that performer's responses are followed by an empty gap for the second player's response, in this case the computer. Therefore, we use a silence detection system (the DetectSilence class in SuperCollider) to detect the start and end points of the human responses. This allows us to estimate the length of the bar, calculate the tempo, and split the bar in two parts, in the second of which the computer responses are played. We average the tempo of the last two bars to get a stable estimation. This technique fits well with txalaparta performance, where the tempo is in constant negotiation, and players who tested this feature reported that it felt natural. An onset detection system (the Onsets class in SuperCollider) reports the number of strokes within each human response, and the amplitude of each stroke is analyzed with SuperCollider's WAmp class (a windowed amplitude follower that averages the absolute value of incoming signals received during the stroke). Finally, the analysis of the timbre, performed with the Chromagram class, allows us to identify which planks are being struck. In this case, we compare the timbral data from the current stroke with the data from a reference stroke of each plank in the txalaparta that is being used, which has to be provided in advance. This system fails only when comparing

Figure 3. Screen capture of the main windows of the Autotxalaparta software. The main controls are in one window (a), while the other window contains aids to help visualize the rhythm (b).

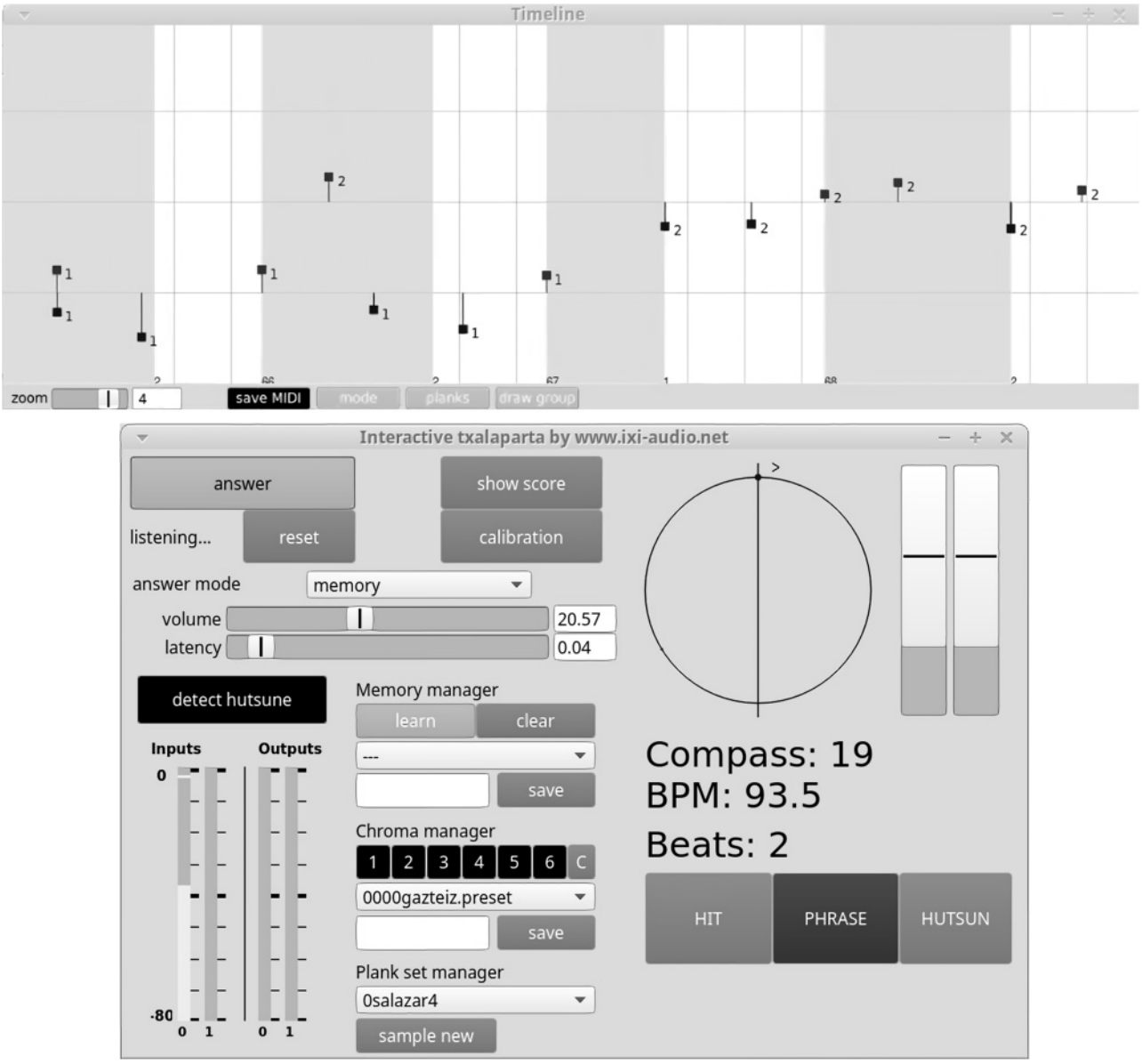


planks of similar timbre (something txalaparta sets usually avoid). For more details on the analysis techniques used see files TxalaOnsetDetection.sc, TxalaSilenceDetection.sc, and TempoCalculator.sc at http://github.com/enrike/txalaparta.

The analysis system can be calibrated to accommodate txalaparta performers' playing styles and their instrument's sound. The calibration must be performed manually, using a small popup window with sliders, and tested by trial and error. Apart from using a microphone to receive the input, other options could be explored (e.g., using piezo microphones) but we decided to focus on simplicity and equipment to which the user is most likely to have access (e.g., a standard microphone or even simply the microphone built into a laptop). Approaches involving machine learning and more sophisticated machine listening could also be explored to analyze the data, but we decided this was beyond the scope of our research at the current stage of our work.

The data generated by the analysis system is, by default, stored into memory as the user plays (this can be toggled on and off with the "learn" button

Figure 4. Screen capture of the Interactive Txalaparta software. The piano roll visualization is in the top window. The main window contains the controls (left side) and graphical elements providing visual feedback of the computer's output (right side).



under the "Memory manager" label) and is later used to generate computer responses. On the one hand, we store the symbolic description of the human responses classified in four groups, depending on their number of strokes. This symbolic description contains, for each stroke in each response, information regarding amplitude, the plank hit, and the time between the current stroke and the first stroke of the response to which it belongs. On the other hand, we keep updating a transition matrix with the data from the changes between numbers of strokes of the current play (rest or one, two, three, or four strokes). For example, txalaparta player A might play two strokes, to which player B might answer

stroking three times; and similarly. All this data can be saved by the user in a text file to be later reloaded. This allows one to subsequently reuse and feed the application with different sets of data corresponding to different txalaparta styles or constraints to be applied to the system.

In a similar fashion to that faced by txalaparta players, to construct a computer response we need to decide upon the following options: when to issue the response; how many strokes the response will have; average time distance between strokes of the response; overall volume, as well as the relative amplitude of each individual stroke; and, finally, which plank and where within the plank each stroke hits.

The GUI allows the user to switch between three answering modes using the "answer" pull-down menu. The menu provides the modes "Imitation," "Memory 1 Bar," and "Memory 2 Bars." The Imitation mode just tries to respond with an exact replica of what its human counterpart plays. This mode is useful to test the calibration of the analysis system. The two other answering modes use a combination of techniques including reuse and adaptation of data collected from the human performance, together with Markov chains and weighted random values. The only difference between those two modes is that each uses Markov chains of different orders. The Interactive Txalaparta tries, as any human txalaparta player would, to accommodate and follow the human tempo, amplitude, and average time between strokes of responses. As for the other options available when building responses, we use Markov chains to decide how many strokes new responses should have, following a long history of using Markov chains in computer music to generate notes and melodies. Possible states in our Markov chain are: rest (0), 1, 2, 3, and 4 (see Figure 5). As noted, the information in the transition matrix is constantly updated to reflect the decisions the human performer takes when answering the machine.

Once the Markov chain decides the number of strokes for the next response, we choose randomly, from the collection of symbolic descriptions of previous responses by the human performer (which is constantly updated), one with the requisite number of strokes. The symbolic data of the chosen response must then be adapted to the current conditions of tempo, average amplitude, and average time distance between strokes of the same response. This is done by stretching the time distance between hits and recalculating the amplitudes. The plank pattern (i.e., which plank corresponds to each hit within a response) is copied from the symbolic description of the human response we have just chosen. We considered creating Markov chains to generate those patterns, but the number of planks in txalapartas can vary from one to seven planks (in some cases, even more). This means that the states and transitions in the Markov chain describing the plank patterns would grow exponentially with each plank added to the txalaparta.

Finally, as described above, txalaparta players strike different areas of each plank to play with timbre variations, tending to concentrate more in some areas of a plank. Once a plank has been assigned to a hit, when we create a response, we perform a weighted random choice in deciding to which part of the plank the stroke should be assigned. The weights were estimated by observing txalaparta performers playing, but the weighting was also discussed with the performers. We then take a sample that corresponds to that area of the plank and that better matches the current amplitude conditions.

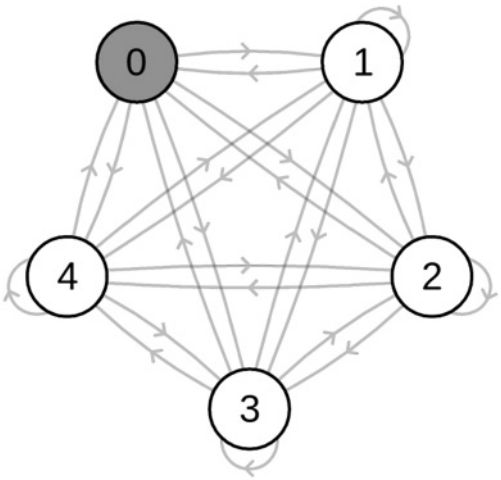


Figure 5. Diagram of the Markov chain that describes the possible stroke options for txalaparta players. (Image produced with markov.yoriz.co.uk.)

Graphical Aids

We designed graphical representations (as shown in Figures 3 and 4) of the software's rhythm to allow performers to understand better the computer's output, since we found that visual feedback (even if only seen by peripheral vision) proved crucial in txalaparta performance. When a human plays the txalaparta, the body gesture of the player to perform a stroke starts immediately when the previous one finishes, the body, and particularly the arms, are in constant movement. This is an important part of performance, and it helps players to predict their partner's actions, as we observed in performances with early versions of our applications. This gestural element of the performance required us to develop a system of visual feedback when playing with a computer. The first visualization system simulates the up-and-down movement of the txalaparta sticks using animated sliders that simulate the movement of the sticks (top of Figure 3b, top right of Figure 4b). The second system is a circular representation of the bar where the last response's strokes played are drawn (below the slider representation in Figure 3b, to the left of the sliders in Figure 4b). In this circular representation, time is mapped clockwise, and it helps visualizing the time distance between the strokes of the same response as well as their amplitudes through the sizes of the small circles (as seen in Figure 3b). This last system is based on a figure from an article by Sánchez and Beltran (1998) used to describe the way the bar is split by interpreters in txalaparta performance. Finally (and only in Interactive Txalaparta), we created a piano roll–like system (Figure 4a) that displays the strokes as they are being played. It follows some of the conventions of the txalaparta scores, such as representing the strokes with vertical lines across a long horizontal line, but we also introduced additional features to allow better visualization of the different parameters of play.

Evaluation

From user testing we learned that performers who used the software were generally positive about the experience. For all of them, it was the first time that they could improvise txalaparta with a computer (see Figure 6). This situation led to questions on the txalaparta play itself and the way interpreters interact with each other. The latter should be a subject of further research, examining the roles of visual feedback (as discussed earlier), memory, and social aspects of the players' interaction functioning over and above the basic musical rules of performance. The development of the software made apparent that players were interested in improvising with the computer as a second player, which was something we did not expect. Txalaparta performers found that playing along with the Autotxalaparta felt rather aleatoric compared to playing with humans. Playing with the Autotxalaparta is a radically different situation to that when human performers play. Human performers must listen carefully to each other to negotiate meaningful txalaparta rhythms, but the Autotxalaparta does not listen or react in any way to the interpreter's play. The techniques we use to generate the rhythm in the Autotxalaparta seem to create convincing txalaparta music but only for a limited span of time and only under certain configurations of the application. After a while, interpreters felt as if the music was not going anywhere, because it did not build any structure. They felt the Autotxalaparta should be able to develop musical structures on a longer term, as well as to engage with the live performance. In other possible configurations of the application, the computer generate performances were simply too distant from a human performance in that they were too irregular.

It was interesting to observe, however, that all users felt that both playing with the Autotxalaparta or listening to the rhythms it generates, whether they felt those rhythms were correct or not, was an enlightening experience rhR strengthened their self-awareness of the strategies they develop while interacting with another human. When the computer generates "weird" txalaparta music, the tacit rules describing "normal" txalaparta music unfold. The Interactive Txalaparta, however, produced almost the opposite reaction. Interpreters thought it should be able to introduce new ideas in the play, be more creative, and diverge from the consensus.

Figure 6. Single txalaparta player improvising together with a computer running the Interactive Txalaparta software.

We believe that the fact that in the Interactive Txalaparta we are using the data extracted from the human play to generate the responses allows the software to feel realistic. At the same time, however, this means that the application does not diverge from the ideas proposed by the human, it follows them too closely. This is probably why they found the program too docile. The txalaparta improvisation is based on a constant negotiation between the interpreters where they tend to play around the agree-disagree dichotomy, often following each other, but also contradicting and opening new directions which might or not be followed by the other interpreter (see Videos 6 and 7).

The use of Markov chains with different orders did not seem to make a great difference to the generation of structures, but we did not have the time to fully explore and test the differences in the music so generated. This is a factor for further research. Despite the limitation in structural coherence, interpreters who used the Interactive Txalaparta were intrigued and found the experience fascinating. From our perspective, this feedback helped us envision different features to develop, such as the visual feedback systems, the calibration system or the system to sample sounds from any txalaparta. We presented a preliminary version of our research at the Txalaparta Congress in Pamplona in March 2015. We were delighted to discover that practitioners found our approach interesting because of the questions it arises about the nature of the txalaparta and its play, even those who had never previously considered using a computer to make music. Our concerns that the txalaparta community would be skeptical about digital software were thus lowered. The community has shown itself to be interested in innovation, collaboration, and alternative approaches to study the practice. This

is perhaps a result of the txalaparta's history as a practice that was rediscovered by the avant-garde in the 1960s, a fact that cannot be so easily projected onto other traditional folk music. More recently, during January 2019, we played the Autotxalaparta and the Interactive Txalaparta in two concerts together with one of our collaborators, an artist known as Ibon R.G., in an experimental pop-folk project. The applications, together with a real txalaparta, were used to arrange some of the songs composed by the musician. The response by the public and in the media was positive, and we found that it was interesting to use the programs both to play "normal" txalaparta rhythms and also to explore combinations that the software allows but no human interpreter would ever play (due to tacit rules). This influenced the way we played the txalaparta in those concerts and we tried out options outside the conventional styles of playing.

Finally, we also conducted an online survey among txalaparta players with questions about the txalaparta and their opinions on the changes it has undergone since the 1960s. This was the first survey ever on txalaparta and it provided us with many insights on several aspects covered by this research, as well as helping us to frame many aspects and ideas about txalaparta performance (cf. Hurtado 2015, pp. 185–188). For instance, we noticed that there is an intense debate over the rhythmic and organologic changes the txalaparta has undergone in recent decades. Another problem is found in the different opinions regarding txalaparta notation: Although some practitioners reject notation altogether, others are enthusiastic. We also collected interesting data on the nature of txalaparta that should be subject of further research. There are, for instance, different approaches on txalaparta that seem to exist between trained and untrained musicians, especially in relation to improvisation; and the divergent understandings of the txalaparta nature that performers express. (A small group strongly supports the idea that the txalaparta is a type of rhythm rather than an instrument. Others do not support this claim, but most performers support both ideas.) To sum up, players who worked with the software became more aware of the tacit rules they apply when playing, and for some of them it opened up a space for a more "outside-the-box" way of playing that explored the limits of the current txalaparta.

Conclusion and Future Work

This research into the txalaparta and the resulting software has portrayed the practice as highly heterogeneous and multifaceted. We have found that this is a consequence of its peculiar history with an unknown past and a period of resurrection in the context of experimental music and avant-garde art culture during the 1960s and 1970s, as well as the mutual historical and formal links between txalaparta and contemporary music. Much of the common interest exhibited by artists and musicians on txalaparta can be explained by how contemporary it feels: its formal characteristics, such as the lack of defined rhythm and tonality; the use of collaborative improvisation defined by generative rules; the exploration of timbre; the economy of the language; the use of repetition and pulse; and the process of using alternation in the construction of the rhythm. This is slowly changing as the txalaparta accommodates to western music in an effort to keep up with times and evolve, however.

Some practitioners claim the txalaparta is a style of playing rhythms and not the physical instrument. We agree that the nature of the txalaparta rhythm is unique, but we argue that the uniqueness of the practice is largely defined by the physical nature of the instrument—its heavy batons, played vertically, the solid wood (or other materials used nowadays), the size of the instrument, etc. We agree with other authors that one of the more distinctive characteristics of the txalaparta in an instrumental and organological context is how the construction of the rhythm emerges from alternate call-and-response performance technique quite special to the practice. This results in a special relationship between the players, as they are not playing together with two instruments: They are one coherent system where skill, timeliness, creativity, personal understanding, etc. render the play an idiosyncratic and unique musical mode of interaction.

Through the software development we have discovered the hard way how many different levels of rule sets there are in the practice. On a lower level, there are rules that determine the musical material (how many strokes and how to define the alternate timings and roles). And on a higher level, there are rules that define how the interpreters interact with each other in performance to construct long-term structures, such as when they repeat a response for a few bars introducing small variations or rework previously played responses. We have seen that some characteristics of the txalaparta are easy to translate to the digital domain (e.g., rhythmic characteristics) while others are more difficult (e.g., richness of timbre). The process of developing the software and engaging with users in software testing has been an enlightening process for all parties involved. By attempting to formalize the rules of the software, latent knowledge became explicit, and practitioners described how the process of contributing in this participatory design development changed their own understanding of their practice. They also remarked that the formalization brought in fresh perspectives. Then there is the software tool itself, which is open source and freely available on the researcher's Web site (www.ixi-audio.net/txalaparta).

Future work will involve the development of more functional and complete software that will allow further research into txalaparta rhythms. We will improve the algorithms that analyze the human performance to overcome the current stylistic limitations, as well as improving system's response to make it more complex and richer, closer to the complexity of the human play. For this, we have begun to apply new techniques developed as part of new machine-learning neural networks. Further plans include the analysis and cataloging of different txalaparta stylistic "dialects" as played by different performers. That way, the practitioners could improvise using this software with a data set from different well-known txalaparta players, which we hope will speed up learning and understanding. The musicological study of the relationship between the txalaparta and experimental music is also a topic that can be deepened, using more in-depth interviews with key participants.

In conclusion, we find that this research is really a starting point for further investigations on txalaparta from the viewpoint of experimental music, given the multiplicity and richness of the aspects we found, ranging from human collaboration, unique performance style, and improvisation to issues of invented tradition and formalized software development.

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