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Electronic_Khipu_: Thinking in Experimental Sound from an Ancestral Andean Interface

Abstract: A khipu is an artifact used in the ancient Inca Empire and previous Andean societies to process and transmit statistical and narrative information. It is known as one of the first textile computers, a tangible interface encrypted in knots and strings made of cotton and wool. This system was widely used until the Spanish colonization that banned and destroyed many of the existing khipus. This article presents the creation process of the Electronic_Khipu_, a new interface for musical expression. It takes the form of a MIDI controller, inspired by the original Incan device. The Khipu has been converted into an instrument for interaction and experimental sound generation by weaving knots with conductive rubber cords, thereby encoding musical compositions. The article goes on to document the implementation of the electronic instrument and evaluate its use in live performances. The research also explores the work of significant artists in this conceptual line who, from a decolonial perspective, have transformed and incorporated the khipu into different contemporary expressions of electronic sound art. These works, along with the practical example cited with the Electronic_Khipu_, suggest alternative practices of tangible live coding, computer music, and data sonification. Creative work with sound continues a legacy, almost lost in colonization, of the ancestral practice of weaving knots as code. In addition, some ideas will be presented to enhance the instrument’s performance in the future.

The khipu is an information processing and transmission device used by the Incas and previous Andean societies. The word comes from the Quechua word khipu or quipu, which means knot. With this system, the data was knotted in wool or cotton strings and encoded different types of information.

A khipu consists of a central cord to which secondary strings are attached with knots of different shapes, colors, and sizes. This device constituted a set of signs that could be used to make numerical records or account for important facts or events, as shown in the example of a traditional Andean khipu in Figure 1.

The khipu has been known for its statistical and accounting capabilities. Still, it has been discovered more recently that khipus also contained not only arithmetic data but also economic, social, biological, historical, astronomical, linguistic, and literary records (Creischer, Hinderer, and Siekmann 2010, p. 135; Urton 2003).

According to information obtained from the Lima Art Museum (MALI 2020) from its most recent exhibition, Khipus: Our History in Knots, the Inca Empire developed a system of knotting with decimal positioning in which the knots represented numerical values according to the position they occupied on the ropes.

These khipus are the most studied and currently represent 85 percent of khipus known to date. It has been discovered that this kind of khipu contained information associated with censuses, tax payments, accounting of resources, and other administrative matters. The code that could not be deciphered from the remaining percentage of extant khipus is thought, however, to record a nonnumeric type of information. The exhibition indicates that these khipus could have been used in performative activities or for spreading information, including the narration or recording of historical memories, songs, or poems.

Regarding the interpretation of khipus, Silvia Rivera Cusicanqui (2018, p. 60) argues that, although the most common explanation given to these artifacts is that they were the accounting system of the Incas, but this is not entirely true. Khipus were certainly also a type of propitiatory accounting, a countable translation of desire where promises and commitments, as well as many other activities, were fixed as knots.

There are currently many kinds of research in archaeology, anthropology, and ethnology, most of which strive to decipher the code of the khipus.
A display of these investigations is reflected in the extensive network of references, publications, and related studies collected in the web repository of the Khipu Database Project at Harvard University (Urton et al. 2020). Since 2002 the project has collected all known information about khipus in a centralized and publicly accessible resource. This Western reading and vision of khipus, obsessed with establishing their numerical and mathematical logics, have however turned them into codes without a message (as Roland Barthes considers photography to be; cf. Rivera Cusicanqui 2010, p. 1).

Under Spanish colonization, khipus were banned and a large number destroyed (MCAP 2003; MALI 2020). Colonization avoided their continued use as the highly functional devices for data computation and as tools for creative expression that could accommodate other meanings. For this reason, in contemporary times khipus have been used almost exclusively for observation and study as cultural objects of mostly archaeological interest and not at the fully functional level they originally had. The practical value of these devices has been set aside, overshadowing the function that the logics imposed by research have not been able to decipher: the artistic function.

In this way, with a creative perspective, I wanted to approach this device by proposing a decolonial exercise that would allow me to imagine, in a tangible way, what computer music created by the first textile computer would be like from the learning of the wisdom of these ancestral technologies that colonization had made unseen.

This project has been developed in the framework of the lectures Playful Interfaces, a course focusing on creating new interfaces for musical expression [NIMEs] guided by Enrique Tomás [2020] and Media Archaeology by the artist Gebhard Sengmüller of the Interface Culture Program at the Linz University of Arts.

Using new media, physical computing, video, and sound software, this project aims to bring the khipu back to the present to construct new sound narratives, following the Andean ancestral peoples’ legacy in a symbolic restoration of the erased memory and as a vindication.

Based on the original khipu [Figure 1], the main objective is to create a contemporary electronic khipu constructed with conductive sensors made of rubber cords and a Teensy board [PJRC, Sherwood, Oregon] as a live sound-interaction instrument and MIDI controller (see Figure 2). It is a tangible interface designed to highlight the importance of cultural memory and historic reparation in a NIME.

**Khipus in the Fields of Art and Sound**

In the fine arts, the khipu has been the inspiration and object of artistic production for several artists.
who have used this device in their work and the conceptual root of many investigations, as is the case with the artists Cecilia Vicuña and Jorge Eielson.

Vicuña, born in 1944 in Chile, is a poet, artist, filmmaker, and activist. According to the biography on her website (www.ceciliavicuna.com), her work “addresses the most urgent concerns of the modern world, including ecological destruction, human rights, and cultural homogenization.” She has been studying and making khipus from different artistic domains since the mid 1960s, intending to excavate their value as evidence of a sophisticated culture destroyed by Spanish colonization and a universal human need for communication and connectivity (see Nell Porter Brown’s “Remembering: Information as Art” in Harvard Magazine January–February 2019).

Jorge Eduardo Eielson was a Peruvian poet and artist born in 1924. In addition to his extensive narrative and poetic work, he was known for the reinterpretation of khipus in visual arts, becoming one of the precursors of conceptual art. Eielson saw in the knots powerful expressive codes and aesthetic signs that also became the point of union between pre-Columbian culture and his personal history. He died in Milan in 2006 (further details in his biography: Canfield 2007).

Within the field of electronic media and sound art, I would like to highlight the work of three representative artists from different latitudes in Latin America who have given voice to the knots, turning the khipu into a living, woven fabric of sound in the present, with artistic research that seeks to vindicate the ancestral technologies of the Andes.

Khipu: Electrotextile Prehispanic Computer

The project Khipu: Electrotextile Prehispanic Computer, conceived by the Chilean artist Constanza Piña (also known as “Corazón de Robota”), received an honorable mention of the Ars Electronica 2020 in the category Interactive Art Plus.

The work was produced in an experimental, creative laboratory in Mexico in cooperation with five other women who wove a large, open-source astronomical khipu, using copper wires mixed with alpaca wool. Using knots reinterpreted from the binary coding system studied by Gary Urton (2005), they encoded astronomical information, stellar events, and natural phenomena such as eclipses or earthquakes that occurred during the khipu’s production period.

In the exhibition, each string with the woven knots represents a different frequency, thus becoming an electrotextile antenna that receives analog electromagnetic signals from the environment, sonifying the invisible spectra of room in a digital synthesizer that amplifies space that is usually visible but cannot be heard (Piña 2017a).

Piña (2020) affirms that the disposition of the work in the exhibition space turns it into a performative installation in which interaction and execution can be produced by a performer, the audience that visits the piece, or the sonified information that it registers from the surroundings (see Figure 3). A sample of the sound and the installation performance can be seen at https://youtu.be/K1XCmKQvFo.

Hanap Pacha Quipu and Quipucamayo

In the course of her career, Peruvian artist Paola Torres Núñez del Prado has been working with traditional Andean and Amazonian textiles, merging...
them with new technologies in a sort of syncretism that brings together the ancestral wisdom of the original peoples with the western knowledge imposed during colonization.

In what Torres (2020a) calls “sonified textile performances,” she presents three textile controllers that she includes in the category of “smart textiles.” She wants to offer another approach to the idea of technology on the margins of Western heritage; it is about soft interfaces to approach experimental practices for sound art.

One of the interfaces used in this sound performance is the Hanap Pacha Quipu, an instrument based on a traditional cotton khipu whose interaction allows the reinterpretation of a stanza of the polyphonic composition “Hanap Pacha Cussicuinin” written in Quechua in the 17th century by a Spanish priest, a musical piece that from its syncretism refers to convictions of European Christianity intertwined with traditional symbols of the ancient Andean cosmovision (project discussion available at https://youtu.be/KwOQRVl39g0).

On her website at autodios.github.io/media/2.mp4, it is possible to see the device and hear the sound it produces.

More recently, Torres has continued to study the khipu and the possibilities of machine learning for its understanding, imagining other ways to give voice to the knots with the assistance of artificial intelligence (AI), inspired by the work of Peruvian artist and poet Jorge Eielson—who had also worked with khipus. In July 2020 Torres released the album El Tiempo Del Hombre [The Time of Man], a record of AI poetry resulting from this process (described in a note in The Wire, 6 August 2020, “Paola Torres Nuñez del Prado Gives a Voice to the Quipus on AI Album”).

In the line of her tactile work with the khipu, Torres (2020b) is working on a future interface for live coding by knots, called Quipocamayo, to generate and modify sounds through knot making in relation to the combinations of knots and strings used.

It is important to point out this work, as it approaches the idea of tangible live coding, an early concept in development, upon which I will expand later in this article.

Devenir Khipunk

With the premise of creating Andean science fiction stories, imagining how we would use the ancestral technologies today if colonization had not existed, the Ecuadorian artists José Luis Jácome Guerrero and Noé Mayorga Ortiz Khipunk created Khipunk, a multidisciplinary artistic approach.

From this more conceptual aspect, Jácome (2020) has composed a sound performance called Devenir Khipunk, which he describes as a “live set” in which he uses a score system generated from the schemes of Carlos Radicati’s study of khipus. Radicati was an Italian historian who studied khipus in the 1950s.

In this work, Radicati’s schemes help Jácome to generate a four-channel composition with random and interpretative sounds, based on an extranumerical sequence.

As instruments, he uses a bass and a four-track analog tape recorder, with each channel assigned to the data of the khipu’s subsidiary lines that interpret knots, colors, and length, which can be manipulated in live performance. A video of Jácome’s performance is available at https://vimeo.com/401973669.

In this example, the khipu study is used as a score to drive the performance, making a sonification from his appreciation of the khipu schemes created by Radicati.

State of the Art at the NIME Conference

After reviewing New Interfaces for Musical Expression conferences for references, I found no records of khipu use in previous NIMEs. Still, because of its cultural character and historical value, I would like to mention some remarkable projects that have taken old traditional musical instruments from different parts of the world and reused them in new interfaces: Among them are the gyil, an African xylophone (Trail et al. 2012); the bodhran, an Irish frame drum (Marshall, Rath, and Moynihan 2002); or the transformation of the HyperPuja for the interaction of the Tibetan singing bowl (Young and Essl 2003).

In the course of reviewing previous work presented at NIME, we see that what many of the
traditional instruments discussed in this article have in common is that they have undergone an electronic transformation, such as the ESitar controller based on an Indian sitar (Kapur et al. 2004), the medieval tromba marina (Baldwin et al. 2016), or the SlowQin as a reinvention of a Chinese string instrument, the guqin (Ho, De Campo, and Hoelzl 2019). Then there are the eHaegum, the eJanggu, and the ZiOm, a set of modified Korean musical devices (Kapur et al. 2013).

There is also the case of traditional instruments that were reused as MIDI controllers, such as the series of instruments making up the Gamelan Elektrika, inspired by traditional Balinese practice (Pardue et al. 2011); or the Mutha Rubboard based on the instrument used in the Zydeco music of South Louisiana in the United States (Wilkerson, Serafin, and Ng 2002).

In another, more recent example, it is worth noting the reflection on the importance of remaking instruments from the past in the example of Persephone Mark II (Gallin and Sirguy 2009). Owing to their decolonial character and the process of creation they have had, one should not omit the Pandivá and the Giromin, electronic devices inspired by the tools used by local communities in Brazil (Barbosa et al. 2015).

Among other kinds of artifact related to media archaeology and repurposing in NIME, there are Music’s Cube, based on a Rubik’s Cube (Polfreman and Oliver 2017), and Cembalo Scrivano, an audiovisual installation inspired by an old typewriter (Lepri and McPherson 2018).

Although most of the references mentioned above refer to musical instruments (which is not the case of the khipu), I have applied and been inspired by these methodologies of reusing a historical artifact and the modifications to extrapolate from the original to the needs of the present, as can be seen in the example of the Tibetan singing prayer wheel that works with gestural control (Wu et al. 2015).

**Yupana and Generative Music**

To conclude this research review, I would like to include another artistic allusion that has used technology from the native peoples of the Andes for contemporary digital sound creation. Umberto Roncoroni Osio (2019) has been inspired by the yupana, another ancient technological device used in the Andes as a calculator. Unlike the khipu, its functions are exclusively mathematical and for the purposes of accounting. Roncoroni suggests some possibilities for generative art derived from the hypothesis of the yupana’s numerical use, reminiscent of using the Turing machine to produce generative music. Roncoroni explains that the design of the yupana and the rules of its use can be modified to represent musical information and to generate rhythms, melodies, and structures of different complexities.

**Electronic Khipu**

The khipu has three-dimensional encoding and is a tangible computer system that requires the whole body. Over and above the sense of sight involved, both touch and hearing are also fundamental parts. The voice was important in the traditional khipu since the information presented in the knots was completed with speech and mnemonic exercises (Sandoval 2019). With this device, the mind computes, and the hands knot the information that remains stored at a tangible level.

With these characteristics, I have designed and built the Electronic Khipu as an instrument in a MIDI controller for experimental sound in which the interaction is based on the weaving of different kinds of knots in real time. In this case, making an analogy with the traditional device, hearing is necessary to understand the sonified knot in live performance.

**Technical Description**

As shown in Figure 2, the Electronic Khipu consist of a main, or “root,” cord and nine secondary strings made with conductive rubber string sensors arranged on a box with potentiometers to modulate volume and buttons to activate or deactivate the signals from each string.

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The Electronic Khipu has a circuit board designed to connect the strings to components that allow their operation, as well as a Teensy microprocessor that sends the signals received from the rubbing of the strings to be knotted. The device also includes a cable attached to one of the performer’s fingers and connected to the ground of the instrument. Manipulating the instrument by these means sends different types of MIDI signals to the computer.

The computer receives these signals as impulses and frequency changes in MIDI signals that control effects in recorded samples and produce other sounds using a digital audio workstation (DAW).

In the following sections, I will detail the production process of each of the parts that constitute the instrument.

Cords

Inspired by the traditional wool khipu (Figure 1), the Electronic_Khipu_ has nine strings of conductive, rubber-cord, stretch sensor attached to a main rope of cotton. Eight ropes range from 20 to 24 cm in length and one central rope is 27 cm long (measured with neither tension nor knots in the strings). After a search of conductive materials and reference projects that had the properties required, the conductive rubber sensor strings were chosen over existing conductive textiles and threads, because the former act as a variable resistance made of carbon-impregnated rubber that is generally used for measuring stretch forces (www.adafruit.com/product/519).

The conductive rubber strings of the Electronic_Khipu_ are flexible and durable; they can be knotted and untied, returning to their original length after stretching in performance. They are also variable resistances that, in addition to measuring the tension created by knots, are sensitive to the performer’s touch and skin conductivity, suggesting a unique sound gesture and another level of embodied experience.

Each string’s tension has different values during the performance; this produces different intensities that are mapped by the audio software to changes in the sound. The strings, as discussed above, are made of conductive rubber. Therefore, they are variable resistances that can be modified depending on three factors:

1. When the string is neither under tension nor being manipulated, stable, constant values are produced.
2. When the string is being knotted and is exposed to contact with the performer’s skin, the values begin to fluctuate, dynamically changing with the location of the knot and the force with which the string is handled.
3. When the knotted string is under tension and placed on the metal support, as shown in Figure 4, the values return to being stable and constant, but are different in relation to the initial state of relaxation. The tension in this state depends on the number and shape of the knots, as the tension produced by a small knot is not the same as that produced by a larger one.

Base Box and Electronic System

As was illustrated in Figures 1 and 2, the arrangement of the Electronic_Khipu_ in a box is based on the exhibited forms of khipus in museums, with strings separated further apart for their better appreciation and use.

Strings are anchored to the upper part of the box with screws; the main cotton rope hides this
connection. The lower part has small conductive metal fittings connected internally to the microcontroller ground, allowing the circuit to close and receive a stable signal from the cord tension after it has been knotted.

To facilitate its use, a button has also been added to the controller for each string, allowing it to be activated in the DAW, and a knob is added for controlling output volume. Finally, there is a banana socket connecting the performer to the instrument.

Inside the box, all the wiring for all the components is arranged in a modular fashion and connected to the Teensy 3.6 microcontroller on a circuit board specially designed for this purpose. The Teensy board was chosen for its versatility in converting sensor and MIDI transmission signals compared to other microcontrollers, and for the number of analog pins on a small board, allowing the interface design to fulfill control needs.

Connecting Performer and Instrument

The variety of sound textures triggered by the different signals produced by the cords is possible in conjunction with the performer’s skin conductivity. The touch and force used to make the knots produce different intensities. The connection is made from a cable connected with a banana plug internally in the ground of the system to a ring or bracelet worn by the performer, thus closing the circuit when the fingers touch the string, modifying the signals produced by each of the strings with this interaction.

When the knots are made, the string is anchored to a small metal piece fixed to the box that connects it to the ground of the electronic system, in a stable way graduated depending on the tension generated by each knot.

Sonority

The Electronic_Khipu_ is a versatile instrument. It allows expressive manipulation of the strings to process sounds, where the gesture and touch have a crucial role in the interpretation. Its feature as a MIDI controller allows the performer to play with different sounds and to modulate effects organically and experimentally.

The Electronic_Khipu_ can be used with different software programs; its sonority is thus directly related to the goals of the composition and the mapped sounds. But after the experiences with the instrument, which will be discussed in greater detail in the section “Evaluation in Live Performance,” I can describe some examples that can be taken into consideration for its use and that influence the sounds produced.

For the first performances (see Cadavid Hinojosa 2019 and the video recording at https://youtu.be/OCpQVPt3Vw), I used Ableton Live as the DAW. Each string was assigned to a track with a sample modified by a chosen effect from the software.

In this case, the values produced by the string handling and knots were mapped to modify parameters such as frequency, note, transposition, modulation rate, or pitch, with the effect applied to the sound, such as “Noise,” “Gamma Rays,” “Top Spreader,” “Hiss,” or “Grains,” producing different textures in performance.

In more recent experiments (a video example is available at https://vimeo.com/445409362, and as can be seen in Figure 5) I worked with Pure Data, using knots, tension, and tactile contact with the strings to map the values received to frequency changes of the band-pass filter in a noise~object.

On the other hand, string length is also a dominant factor, because it allows higher or lower tensions according to the number and size of the knots woven into the strings.

As noted earlier, eight strings have similar lengths in this instrument, with a longer central string, since this string was designed to be woven at the end, leaving more space to play with more knots and tension.

Creating Computer Music Using the First Textile Computer

According to Piña (2017b), to understand the khipu it is necessary to venture into making one. Through making knots it is possible to understand how the instrument works and to learn to read and write it by weaving the codes.
The Electronic Khipu is a NIME, in which the process of its development went closely hand in hand with the experience gained through learning from the original ancestral device, as well as from all the knowledge behind the research that lies beyond the strings. In this case, to deeply understand how to play the instrument, one must first have the experience of making and knotting the khipu.

In ancient times khipus were knotted only by khipukamayuqs [khipu knotters] [MCAP 2003], who dedicated their entire lives to the codification, reading, and archival of these devices. They were the computer systems engineers of their day, philologists of knots, astronomers, poets, accountants, historians, statisticians, and mathematicians. They concentrated on their knowledge, art, and science without need for honor or status. In performance with the Electronic Khipu, the figure of the khipukamayuq takes on special importance, since it is represented in the performer, the live coder, the person who encodes the data in the knots, who can connect to the meanings of the knots and produce the sound.

The performer becomes a contemporary khipukamayuq who, in a kind of tangible live coding, records and encrypts a live sound composition through the knots.

Approaching an Early Idea of Tangible Live Coding

Live coding is an artistic practice that consists of creating and modifying algorithms to generate music and images in real time, often while projecting the code in front of an audience [Roberts and Wakefield 2018]. This is usually done with the computer using programming languages and software designed for these purposes.
To understand the possibility of the practice of tangible live coding using the khipu, it is necessary to consider this device from a decolonial perspective, understanding the existence of ancestral technologies that emerged before the colonization and other unexplored possibilities for constructing algorithms and writing code. The khipu is the root artifact of many technologies that have been made invisible, a computer that involves the body for its logic and functioning.

In this case, the hand-coding by knotting the khipu allows one to think about its use in a kind of alternative practice of tangible live coding, using knots instead of a keyboard, where the code is written, modified, and transformed in the work of knotting, generating different sound textures and tensions that are more organic. The algorithm is knotted live, and the audience can perceive the changes and make direct associations between what is projected and what is heard.

Torres (2020b) offers another, similar perspective regarding the algorithm’s construction and binary code. In the section “Heritage Algorithms” of the past workshop series Hybrid Live Coding Interfaces: Performance and Craft, she presented the first steps of her work-in-progress Quipocamayo, a project described in the section “Hanap Pacha Quipu and Quipucamayo.”

With Quipocamayo, Torres wants to create a binary knot-recognition system that allows her to create algorithms to trigger sounds, inspired by the traditional khipu numerical knot system. She makes an interesting analogy between weaving and live coding:

In this way, gesture (the act of tying knots) is part of the live coding performance as craft, going beyond the keyboard and screen combo, in a way, evoking more traditional orchestral performances while presenting a different approach to audiovisual presentations where textile and fiber manipulation take the lead role in what visuality and gesture is related, in turn, recontextualizing sound (Torres 2020b).

In another layer and materiality, this idea could be incorporated into the concept of tangible live coding that I present using the Electronic_Khipu.

**Evaluation in Live Performance**

The first deployment of the Electronic_Khipu was tested in the performance “Knotting the Memory // Encoding the Khipu” in which the instrument is the primary interaction element. The performance was composed to pay tribute to this device.

In a more reduced form, as an extension of the first experiences with the instrument, I have also used it to experiment in a small piece called “Tawa,” which has allowed me to explore the use of the controller with open-source software such as Pure Data.

**Knotting the Memory // Encoding the Khipu**

The Electronic_Khipu was designed for a live sound-playing experience whose code can be known and produced by live experimentation in the act of knotting.

Initially, I used and applied some traditional forms of numerical coding of knots (Urton 2003) and my own interpretations of knots generated in rehearsal. The purpose of the performance is not to decipher the code of the knots, nor is it to teach the language of knotting to the audience, nor even is it to explain what the device is or what it does. The performance wants to bridge the ancestral media and the current technology in claiming the most practical facet of the device.

On a more individual level, I can describe my experience as a performer as a channel of connection with my origins, finding the path to knot together personal memories by creating my own codification of stories through sound. The personal experience of playing with the Electronic_Khipu could be translated to sculpting the sound with the hands through weaving.

Despite its experimental character, like any instrument that gains in mastery through practice, once one is familiar with the strings, the elasticity, the effects associated with them, their sounds, and the capacity to write through the knots, it is produced by playing produces a sense of malleability that controls and generates the sound by touch, literally weaving it.

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Figure 6. Score used to play the Electronic Khipu in the first performances.

I have performed this piece on several occasions and the live experience was different each time, even though I follow a fixed structure in the form of a score like the one seen in Figure 6. The mapped values and the sounds are the same, but the instrument gives a unique character to each performance.

Choice of Sounds

The composition of this first performance was conceived mainly in terms of experimentation and evaluation of the interface’s coherence to the concept and its cultural context. I used Ableton Live 10 as the DAW. Ritual ambient sounds with different effects were used, ranging from subtle noise to sounds with melodic shades and recordings of traditional instruments of the Andes, up to denser and deeper textures to finish the composition. A video excerpt of the performance is available online at https://doi.org/10.1162/comj_a_00561.

The selection of sounds was arranged so that after mapping the strings, the effects would produce a better response the performer’s touch and interact better during the weaving process.

Each string was associated with a sample and its signals were mapped to a different effect that allowed the sound density to increase. In the performance, I used sounds from the ambient and evolving Ableton samplers core library such as Pitched Ambiente, Dark One, and Chill Outzone, mapped on the side strings with different effects.

For the central strings, I have used a sample recorded from a rain stick, a traditional instrument with a rich textured sound, processed by “Gamma Ray,” “Grains,” and “Top Spreader” Ableton effects. Each string produces one signal that might be mapped to one or another of the parameters in the effects such as frequency, modulation rate, and pitch.
Figure 7. MIDI mapping of the strings with sounds, effects, and volume in Ableton Live.

Figure 7 gives an impression of the details in the MIDI mapping of the performance session with the mapping values applied to each string in Ableton Live.

Besides the sound produced by the strings, the performance also has some accompanying sounds that emphasize key moments of the piece, like the sound of a bombo leguero (an Andean bass drum) that marks a constant and deep rhythm anticipating the knotting of the central string. As another example, the sound of a zampona wind instrument in rhythm with the bass drum complements the sound of the strings and the sound of the rain stick, but without any effect applied.

In the composition I use the same sounds to start and close the performance. In the first performances,
it was a white noise sound that complemented the “Wind Machine” sound of the Ableton pack, mapped to the first string to be knotted. In other performances, I have used a sample of the sound of cacerolazo (banging of pots and pans) recorded from the videos in the protests in Colombia in 2019.

**Graphic Representation**

As in the practice of live coding, the performance has a projection displaying the code that builds the sound; in this case, it shows the knotting work, the direct connection between the manipulation of the strings and the generated sound. (The example of live use of the visuals can be seen in the video excerpt online.)

To process the visuals, all hand movements and gestures of knotting are captured by a camera in real time using the software vvvv and the texture filter “edge,” with the radius and brightness values modified to create a white linear image on a black background as a living drawing, as can be seen in Figure 8.

Its design provides useful visual and tangible feedback to the performer and immerses the audience in the experience when the knots are being projected live during the performance.

The diagram in Figure 9 shows the general technical disposition in an instrument to the performance.

**Live Performances**

“Knotting the Memory // Encoding the Khipu_” has been presented at venues and festivals such as the 2019 Ars Electronica festival and in the Deep Space 8K venue of the Ars Electronica Center, as well as other spaces that have allowed the instrument to be adapted to different stages.

In 2020, it was transmitted in an online format, both in the Reimagining Historical and Everyday Objects section of the NIME conference’s music track and at the 16th Athens Digital Art Festival.
A brief description of the audience’s general appreciation after the presentation in different venues is based on contemplation. With a score that is knotted live, the experience has been perceived as a sound narrative that is generated as the device is knotted, a story that is coded live through the knots, with several layers of sound that immerse the audience in the woven memory whose interpretation is associated with the movement of the hands in the knotting.

Since doing her research, Colombian composer and live coder Laura Zapata has also referred to this project since her research as an alternative way of thinking about the code to create and visualize memories in knots, suggesting a different vision from the Western norm [cf. Terceros 2020].

**Conclusions and Future Work**

The Andean khipu is an ancient technological device that continues to be the source of inspiration for many artistic works related to sound today. Its cultural heritage bridges the gap between art, science, and sound, with possibilities still being explored.

In this article I have presented results that have been obtained from an ongoing theoretical and practical investigation, considering the process of creating the Electronic_Khipu_ and its uses as a MIDI controller and as a NIME. I have also reviewed references that have directly or indirectly incorporated similar ideas in creative expressions related to sound and electronic art.

With the Electronic_Khipu_, an early approach is made to what could be called tangible live coding, since the khipu, even transformed into a NIME, is still a computer and the sound results vary in different software from what I had previously used.

As touched upon earlier in the section “Sonority,” in this exercise I experimented with Pure Data and the advantages of the instrument as a MIDI controller using free software. The laboratory results could be seen in an online transmission in August 2020 [https://youtu.be/4NPOEp-sG_Q].

**Tawa**

The Quechuan word for the number four is *tawa*. In Andean cosmology, this number symbolizes the two opposite balances that complement each other [Cantero 2019]. This piece, a small experimental part of the experience with the previous performance, was developed within the framework of the virtual lab “Women on the Verge of Noise: Gender in Sound Creation” with technology by Laura Zapata and Juliana Ortigoza in Plataforma Bogotá.

This time I wanted the Electronic_Khipu_ to map white noise in four frequency bands, employing different software from what I had previously used.

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real time according to the coding made by the knotwork and the different values produced when the strings are tightened. This feature is currently being studied for better implementation in various contexts.

Recently I have been studying smaller electronic khipu designs with different numbers of strings and applying recommendations from personal experience playing in various performances and from feedback received at the NIME 2020 conference.

At the conference, I received different design ideas. First among these was to change the arrangement of the knots and buttons on the box to focus attention on the instrument’s strings. Another idea is to facilitate the instrument’s portability by adapting it to a smaller box with lower height and possibly using lighter materials.

Concerning the sound, I received suggestions about studying other tools and more-efficient ways of mapping the values produced by the strings in order to facilitate their use in other sound software and their learning by new users.

“Knotting the Memory // Encoding the Khipu,” and “Tawa” are the first performances of this instrument. I expect to develop other pieces in which the Electronic_Khipu can be used as a primary element or accompaniment. The development of NIMEs developed by reusing other ancient Andean interfaces could form a series of instruments for audiovisual performance, as the yupana, also known as the abacus or Andean calculator, has been exposed in this article by the implementations of Roncoroni Ossio (2019). I want to continue my practice in a tangible way that allows the physical interaction with this device, exploring its possibilities and sonorities.

The live projection of the coding on the knots [see Figure 8] is an open score that has only been used for graphic representation, as discussed in this article. Taking advantage of this feature, I want to develop a tracking system to recognize the knots in real time and to create another type of sound interaction with the information encoded in the knots.

Following the first steps of experimenting with Pure Data in the performance of “Tawa,” possibilities have been opened to continue exploring the scope of this instrument with other open-source software and with other audio platforms that allow its use with MIDI.

Besides using the Electronic_Khipu, besides its use as a MIDI controller, I would like to explore other facets in the future, such as developing a synthesizer independent of the computer using the same interaction dynamics, with string knotting and sound generation by touch.

This project additionally opens and follows several research paths related to decolonial aesthetics in technology and the treatment of cultural heritage in contemporary creative and artistic expressions related to sound and new media, as well as the exhibition of current references that use ancient technologies in current practices that go beyond media archaeology as recognized from the Western paradigm.

To conclude, I have explained the process of making a NIME inspired by an Andean khipu, emphasizing its cultural value and the new ideas that are knotted from the ancestral tradition in the present.

I have also introduced different artists’ creative processes with similar concerns inspired by this device, finding new technological interfaces that encode sound compositions in knots, suggesting alternative ways to produce computer music.

Recognition for Electronic_Khipu.

This article is a revised and expanded version of the paper “Knotting the Memory // Encoding the Khipu: Reuse of an Ancient Andean Device as a NIME,” [Cadavid Hinojosa 2020] presented at the NIME conference 2020 and recognized with the honorary mention of the Pamela Z Innovation Award of NIME 2020. “Its decolonial aesthetic opens NIME up to powerful questions of cultural agency and historical perspectives” (Jawad et al. 2020).

The Electronic_Khipu is also a finalist in the Guthman Musical Instrument Competition 2021, organized by the Georgia Institute of Technology in the United States, an event searching each year since 1998 for the world’s next generation of musical instruments and the best new ideas in musicality, design, and engineering.
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References


