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Artículos científicos

Cruce de fronteras: hibridaciones artístico-musicales, de la electrónica a la biotecnología

Crossing borders: artistic-musical hybridizations, from electronics to biotechnology

Cruzando fronteiras: hibridizações artístico-musicais, da eletrônica à biotecnologia

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Resumen

Las tecnologías han sido fundamentales en el devenir de las artes, ya que han permitido a los artistas apropiarse de teorías, métodos y procedimientos de la ciencia para convertirlos en parte de su discurso, es decir, en contenido simbólico que adquiere valores de significación. De hecho, en el ámbito de la música, estos recursos resultan relevantes para crear nuevas sonoridades, texturas y timbres, lo cual ha dado lugar a formas innovadoras de componer que van desde algoritmos computacionales e inteligencia artificial hasta elementos biotecnológicos en los que se emplean las propiedades que tienen ciertos tipos de bacterias u otros microorganismos. Existen estudios y literatura sobre el arte sonoro, pero, en general, se ha abordado poco o de forma insuficiente la relación entre estas disciplinas y sus hibridaciones. Por ende, en este estudio se realizó un análisis de obras de arte híbridas contemporáneas que emplean tecnologías digitales, informáticas, electrónicas o biológicas como parte de su poética, lo cual genera cruces en las fronteras entre los ámbitos sonoro, visual y musical. El objetivo fue comprender el impacto de las tecnologías actuales en la producción artística, así como la manera en que dichas propuestas transfiguran los medios tecnológicos en contenido simbólico como parte de su discurso.

Palabras clave: música, arte, tecnología, biotecnologías, algoritmos, composición.

Abstract

Technologies have been fundamental in the evolution of the arts, allowing artists to appropriate theories, methods and procedures of science to make them part of their discourse; that is, in symbolic content that acquires significance values. Its use in the field of music is relevant because, without a doubt, it is where its use in the creation of new sounds, textures and timbres is most evident. Also, it has given rise to innovative ways of composing, taking as a starting point from computer algorithms and artificial intelligence to the use of biotechnological elements in which the properties of certain types of bacteria or other microorganisms are used. There are some studies and literature on sound art, but, in general, the relationship between these disciplines and their hybridizations has been little or insufficiently addressed. In this study, an analysis was made of contemporary hybrid works of art that use digital, computer, electronic or biological technologies as part of their poetics, producing border crossings between sound, visual and musical fields. The objective of this research is to understand the impact of current technologies on artistic production; in addition, the way in which these proposals transfigure technological media into symbolic content as part of their discourse.

Keywords: Music, art, technology, biotechnologies, algorithms, composition

Resumo

As tecnologias têm sido fundamentais no desenvolvimento das artes, pois têm permitido aos artistas se apropriarem de teorias, métodos e procedimentos da ciência para transformá-los em parte do seu discurso, ou seja, em conteúdos simbólicos que adquirem valores significativos. De facto, no domínio da música, estes recursos são relevantes para a criação de novos sons, texturas e timbres, o que tem dado origem a formas inovadoras de compor que vão desde algoritmos computacionais e inteligência artificial a elementos biotecnológicos em que propriedades que certos tipos de bactérias ou outros microorganismos têm. Existem estudos e literatura sobre arte sonora, mas, em geral, a relação entre estas disciplinas e as suas hibridizações tem sido pouco ou insuficientemente abordada. Portanto, neste estudo foi realizada uma análise de obras de arte híbridas contemporâneas que utilizam tecnologias digitais, computacionais, eletrônicas ou biológicas como parte de

sua poética, o que gera cruzamentos de fronteiras entre as esferas sonora, visual e musical. O objetivo foi compreender o impacto das tecnologias atuais na produção artística, bem como a forma como essas propostas transfiguram os meios tecnológicos em conteúdos simbólicos como parte do seu discurso.

Palavras-chave: música, arte, tecnologia, biotecnologias, algoritmos, composição.

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Introduction

The relationship between art and science has always been complex, as it has been supported by approaches that can often be antagonistic and controversial. This relationship, to a large extent, has oscillated between novelty, experimentation, traditional or, in the words of Umberto Eco, between "apocalyptic and integrated" approaches. Therefore, it could be stated that experimentation has been a constant to create sensory, visual, auditory and bodily experiences, where technology has been used as a tool in the artistic creative process.

For example, the development of musical instruments in the 18th and 19th centuries led to greater study of the nature and physics of sound, which contributed to the composition of more complex musical pieces. Although these pieces continued to be performed with conventional instruments, the latter underwent significant changes as technology evolved, and some even disappeared. Subsequently, the technological revolutions of the following century were incorporated into the creative work of artists and musicians, but these touchpoints have been the subject of limited study. In this way, the new artistic proposals gave rise to the production of hybrid works in which the borders between music, the visual and the technological are blurred.

For this reason, the purpose of the following lines is to analyze these interdisciplinary intersections through projects related to music and sound art, in which the use of technology has been fundamental. To do this, we start from the premise that technology is no longer just a means of support, but rather becomes an integral part of the poetics and symbolic-discursive content of the work, which broadens understanding and encourages greater understanding. debate about these intersections generated through artistic, technological and musical hybridizations.

From experimental music to electronic

The 20th century was a period of intense experimentation in the use of technologies in the creation of artistic and musical works. These technologies became key elements in the message conveyed by the works, which is why they influenced the symbolic and poetic content of artistic and musical development. This led to a blurring of the borders between visual and musical proposals, although these crossings are not new and date back to the 18th century. Jacques de Vaucanson, for example, built a prototype automaton that generated music by simulating the playing of a flute and the production of a melody by mechanically moving the fingers in the corresponding holes. His pioneering research addressed the mechanism of sound and harmonics, almost a century before Hermann von Helmholtz's seminal work in *On the Sensations of Tone* (1863).

In the late 19th century, some artists attempted to incorporate symbolic elements from both music and painting, as in the Symbolist movement. For example, Paul Gauguin made deliberate analogies between music, shapes, colors and textures in his painting. A similar approach was adopted by the painter Vasily Kandinsky in the early 20th century, who developed his works based on the relationship between music and colors that arose from his condition of synesthesia. In fact, his correspondence with the musician Arnold Schönberg, where they explored the relationship between music and painting, is widely known.

Furthermore, the composer Aleksandr Scriabin created his symphonic poem *Prometheus* using an instrument called *the Chromola,* which he invented himself. This organ generated colors related to the sounds it produced, reflecting Scriabin's synesthetic condition.

However, it was during the artistic avant-garde that sound was fully incorporated into the visual arts, thanks to the work of Luigi Russolo, who in 1913 published one of the futurist manifestos of music *L'art dei rumori,* in a letter to the musician Francesco Balilla Pratella. The latter had already published a text on *Futurist Music in 1910,* in which he exhorted young people to free themselves from musical traditions and institutions. In this work he highlighted the importance of composers such as Debussy, Strauss, Elgar and Mascagni as innovators who broke with conventional norms of musical composition. Pratella maintained that these great musicians, from Palestrina to Wagner, were, in essence, “futurists” because of their level of innovation. He also advocated breaking down the notion of dissonance and consonance (an approach that Arnold Schönberg would adopt in 1912) and creating a completely enharmonic system based on atonal chromatic values. Pratella 's manifesto concludes as follows:

> Bringing to music all the new attitudes of nature, always tamed differently by man by virtue of incessant scientific discoveries. Give the musical soul of the masses, of the great industrial complexes, of the trains, of the ocean liners, of the battleships, of the automobiles and of the airplanes. Add to the great central themes of the musical poem the dominance of the machine and the victorious reign of electricity. (Pratella, cited by Fubini, 2004, p. 49).

Pratella 's influence on Russolo's *L'arte di rumori* is evident, although the latter took it even further. Furthermore, it should be noted that Russolo, being a painter and not a musician, maintained that the sounds generated by machines, automobiles, factories and others could be considered as sound elements, or more precisely, as "sound-noise." Russolo's explorations culminated in the design of visual-sound objects called *intonarumori* [1], which laid the foundations for sound sculpture. These instruments generated acoustic noise mechanically but allowed control of tones and dynamics. All of these examples represent the first encounters between music, visual arts and technology, which laid the foundation for more complex artistic hybridizations.

For his part, the philosopher Theodore W. Adorno (2003) argued that 20th century music was divided into two directions: the progressive, represented by Schönberg, and the neoclassical restoration, personified by Stravinsky. However, avant-garde artists such as John Cage and Pierre Boulez sought to free themselves from both paths, since they considered that the first was romantic and subjective, while the second was framed in a classical tradition that had already been fractured since the beginning of the century, and that should not be restored. These artists also did not advocate the inclusion of urban elements such as *jazz* or folk traditions. Although Adorno's ideas reflected the music of the first half of the 20th century, later generations viewed composers as specialists, a perspective supported by theorist and composer Milton Babbit.

Babbit conceived of composition as a process similar to scientific research and believed that the contemporary listener should possess knowledge not only musically competent, but also in philosophy, physics and mathematics. These ideas began to have a greater impact from the 1950s onwards, contributing to blurring the boundaries between the visual and the musical.

Subsequently, technological advances played a fundamental role in the changes that took place in the musical field and in the evolution of the new discipline of sound art.

[1]Intones-noises. Own translation.

Magnetic tape, for example, was invented by Germans during World War II and later improved and marketed by Ampex in the United States. Les Paul, a *jazz guitarist* known for his improvements on the electric guitar, was a key innovator in the development of this technology. Previously, in 1941, jazz musician Sidney Bechet had made the first multitrack recording with the collaboration of RCA engineers, where he played practically all musical instruments, creating *overdubs,* which consist of overdubbing tapes to superimpose different layers of sound. (Hernández, June 9, 2021). This influenced Les Paul, who after numerous experiments, designed a magnetic tape recorder with multiple heads that allowed the playback of one or several tapes while recording on others, which marked the birth of the first 8-channel tape recorder.

The use of recorded sounds made it possible to experiment with them and, consequently, blur the dividing line between the concepts of noise and sound. Towards the end of the 1940s, engineers Pierre Schaeffer and Pierre Henry worked with recorded sounds and processed them in ways that generated effects never before heard—that is, they sped up, slowed down, distorted, and applied other effects—transforming the sounds into something unrecognizable. Schaeffer, who had worked with conventional phonographs, found magnetic tape an ideal medium for creating sound *collages,* cutting and splicing pieces of tape. In this way, he developed what he later called *musique concrete,* which consisted of the use of recorded and processed sounds, which led to the dissociation of the sounds from their original source. In this way, sounds were treated as sound objects, a concept that Schaeffer called *sound objects.* Furthermore, he coined the term *acousmatic listening* to describe the perception of "a sound without a visual reference to the source that produces it" (Litch, 2019, p. 50).

Schaeffer 's influence resulted in two main currents: experimental music, focused on new sounds, textures, spatiality and electronics; and sound art, which was more related to the visual arts, a topic that will be addressed later. Furthermore, the notion of acousmatic listening, fundamental not only in concrete music, but also in electronic proposals and sound art, allowed us to explore aspects of perception.

Then, in 1946, summer courses for new music were established in the German city of Darmstadt, with a main focus on the development of electronic music, largely influenced by the work of Henry and Schaeffer. These types of courses and research on music were carried out in various cities in Europe, America and Asia. Musicians began collaborating on interdisciplinary projects with scientists and engineers, working together in studios and

laboratories. Despite the slogan of freedom in the Darmstadt courses, the use of traditional procedures or tonal methods was not well regarded, which frustrated several musicians, such as Henze and Ligeti, who at some point in their careers incorporated neoclassical tonal elements and neoromantics.

In 1954, Karlheinz Stockhausen, after spending time with Schaeffer, published his work *Elektronische Study II.* This composition featured timbres and textures that had never been heard before, as well as the use of notes outside of chromatic or diatonic conventions. Stockhausen 's musical notation included the duration of sounds measured on magnetic tape, the intensity in decibels, and the frequencies of each loudness. This was significant because, as in previous times, musical development was related to advances in musical writing, that is, without the invention of the 5-line score and notation of the 11th century, polyphony would not have been able to develop.

On the other hand, the musician and architect Iannis Xenakis applied architectural principles to his musical compositions, that is, he treated instrumental sound as structures, avoiding constructive ruptures. Thus, he used spatial models in musical writing and developed a highly complex composition method called *stochastic music,* related to the branch of mathematics that studies random systems or processes. Furthermore, he applied these same principles to his designs, thereby achieving a close relationship between both disciplines.

In 1958, Edgar Varèse presented his *Poème électronique* at the Brussels Universal Exhibition, in a pavilion specially designed by Le Corbusier and Xenakis for its interpretation. Varèse reactivated his compositional career through technological experimentation that allowed him to manipulate sound. *Poem Électronique* combined electronically generated sounds with recordings of musique concrete, as well as using images and colors in *collage* form. This piece represents one of the first hybrid works that intertwine visual, technological, musical and poetic elements.

In 1949, John Cage was considered the most radical and influential American composer of his time. Ten years earlier, in 1939, Cage had already composed *Imaginary Landscape No. 1*, in which he used a muted piano, a Chinese chopstick, and a phonograph with variable speeds. Then, in 1951, he created *Imaginary Landscape No. 4,* which involved two performers in front of twelve radios: one adjusted the tune according to the score and the other controlled the volume. This work represented a criticism of the media-saturated society.

Many of Cage's works, although considered musical pieces, were performed through performances closer to *performance* than to traditional forms of interpretation in concert halls. The same applies to *Waterwalk* from 1960, where sounds are produced using pressure cookers, glasses, jugs and even a rubber duck, all measured chronometrically and set in the score, with an important element of chance, combining visual elements, performative actions, musical measures and sound generation, along with technological elements.

Cage taught at the avant-garde art school Black Mountain College and later at Wesleyan University. Many of his students were musicians and visual artists, such as George Maciunas, Allan Kaprow, Nam June Paik, La Monte Young, Toshi Ichiyanagi and his wife at the time, Yoko Ono. This led to the creation of radical proposals in visual and sound terms, such as *happenings and the* neo-Dadaist movement known as Fluxus. Many of these experiments influenced what would become action art and, in particular, sound art.

These experiments found their way into rock music on albums like *Revolver* from 1966 and *Sgt. Pepper's Lonely Hearts Club Band* from 1967 by The Beatles, which surprised the musicians at the Darmstadt courses. It was Paul McCartney who became interested in these proposals, particularly in the music of Stockhausen, and introduced the rest of the group to electronic experimentation. From the use of *loops* (short recordings that are repeated in a loop, and used as overdubs*)* and reverse recordings, special effects generated both analogically and electronically, etc., initiated a new way of composing and recording music.

The first songs they recorded with these new techniques were *Tomorrow never knows* and *Paperback Writer*, where, with the help of his new recording engineer, Geoff Emerick, recording, miking and mixing techniques were also improved to produce more complex sounds, in accordance with the creative needs of Lennon and McCartney. These changes and improvements, of course, also influenced other bands, such as The Who, Pink Floyd, Alan Parsons Project, Soft Machine, among others.

Sound art: visual-musical hybridization, blurring of borders

The influence that music had on the development of sound art is evident, especially from the 20th century onwards, from the work done by Dada and then the proposals of John Cage and the musicians and artists who were part of the Fluxus group. In this way, a hybridization emerged in the way of composing, where technology had greater preponderance and prominence. The sound no longer had this traditional melodic-harmonic-rhythmic relationship, but rather acquired more environmental aspects and allowed reflection

from its production. IN other words, sound is valuable as sound, not from its traditional musical perspective.

One of the first hybrid pieces that weaves together musical, technological, biological, and performative aspects was Alvin Lucier's *Music for Solo Performer* (1960). The composer placed sensors on his head and, using the principle of electroencephalography, monitored the alpha waves of his brain. In this way, through a system of speakers that were around the room, he reproduced low-frequency sounds obtained from the sensors in his head, which made nearby percussion instruments vibrate due to resonance. This piece would be in the line between *performance,* sound art and musical composition based on the use of technologies applied to electro-biological processes.

The term *sound art* can be traced back to the late sixties of the last century, although its popularity has increased to a greater extent since the new millennium. As such, it is a term that has not yet been clarified, but that does differentiate itself from musical practice and is closer to the visual arts, from installation and *performance.* Sound art could be considered in two categories:

> –An installed sound environment that is defined by the physical and/or acoustic space it occupies rather than by time and can be exhibited as a work of visual art.
>
> –A work of visual art that also has a sound production function, such as sound sculpture.[2] (Litch, 2019, pp. 22-23).

Sound is transformed into a plastic element rather than an acoustic one and acquires aesthetic-symbolic values outside the musical field. Sound art can be divided into sound sculpture, sound installation (a term coined by Max Neuhaus) and soundscape; However, *performance* and sound poetry could also enter. Even though many of the representatives of this discipline come from music, sound art is more related to the visual arts, especially due to the interaction with the physical space by the spectators. Russolo's intonarumori already proposed a point of *contact* between sound, space and interaction with the viewer and many of the sound works have to do with interactivity within a given space.

The important thing is that, to carry out this type of proposals, the use of technologies is required: in principle, acoustic reproduction systems, speakers, amplifiers, oscillators, etc. In some of these works, reflective aesthetic discourses and their relationship with the perceptual field are proposed. For example, in *Dream House* (1993), made by La Monte

[2]Own translation.

Young and Marian Zazeela, a visitor enters a room where static, dense, high-decibel sounds are heard, the overtones[3] of which are slightly modified by the movement of the head. If you stay for a long time, it can be like looking at a sculpture from any angle, but its scale can cause a somatic and psychological impact due to the volume and selected frequencies of the sound. That is, it is not only about taking advantage of the electroacoustic elements, but also their psychoacoustic results. They become, therefore, experiential pieces from a sensory aspect. Furthermore, since they are far from the scope of a musical presentation or a concert, many of these pieces cannot be recorded. Perhaps, in the case of sound sculptures, some recordings could be made, but these would suffer from the visual and performative part; On the other hand, the same would happen with some installations or soundscapes that are photographed: in the end these only remain in graphic documents and do not have the complete experiential or sensory aspect that these artistic proposals require.

The starting point, then, is the use of space as one of the fundamental elements of sound art, a situation that was being worked on in some musical pieces such as those by Stockhausen, John Cage or other musicians, although others (such as Raymond Murray Schafer or Annea Lockwood) also used the use of space and recorded sounds obtained from nature, bringing their work closer to the line of Land Art, of which sound art is curiously contemporary. David Dunn, for example, made a piece of sound art in 1976 called *Mimmus Polyglottos,* in which he engaged in a "conversation" with a cenzontle using square wave signals whose frequencies were in the voice range of this bird. At first, he was presented with a series of stimuli to which he began to react and then had a more comfortable relationship with the electronic stimuli to which he seemed to respond. Dunn's work is one of the most interesting in the relationship between electronic music and sound environment and nature.

According to Litch (2019), Raymond M. Shafer coined the term *soundscape,* which is composed of the totality of sounds found in a certain place, which defines its specific acoustic expression, as a sound fingerprint. In this sense, the sounds of each place configure a collective, but also individual, memory for the members of a certain community. Therefore, each change in the soundscape is, at the same time, a transformation in the structure of the environment of that particular place. Thus, sounds acquire values of consciousness and reading that become symbolic language with different and specific levels of meaning. An example of this is the piece *Time Piece Stommeln* (2007) by Max Neuhaus, which the artist

[3] They are harmonic and non-harmonic frequencies that accompany a fundamental note and are determined mainly by the type of material, geometry and other physical parameters. They are also called *partials.*

proposes “as a communal acoustic signal for the Stommeln Synagogue, with sounds of the Halakhic Hours in the square” (Pardo, 2017, p. 41). For this work, Neuhaus examined the community's ways of life, as well as symbolic, visual and acoustic elements. The piece adopts a programmed time following the halakhic hours between sunrise and sunset that are governed by Jewish laws; The sound begins almost inaudibly and increases imperceptibly over a period of many minutes until it stops abruptly to create a sensation of silence. The sounds are emitted thirteen times a day, while the interval between individual signals changes daily in sync with the position of the sun.

A more recent example of hybridization between installation, action and soundscape in city settings is the work *Urban Parasites* (2006-2007) by Gilberto Esparza; The intersection that it makes between technology, the visual part, the sound part and the social aspects it addresses is interesting. The artist gathered technological waste from mechanical and electronic systems with which he configured artificial life organisms that can survive in urban environments. Basically, these “bugs” feed on the cities' electrical grid, so they get their energy from the cables and moving to escape when they feel they are in danger. In addition, they interact with the environment by emitting sounds to communicate with another parasite. These sounds are taken from the same environment, and, in this way, they mix and become part of the soundscape with which it blends in acoustically.

Of computer music, artificial intelligence and the use of biotechnologies such as artistic crossings and hybridizations

Between serialism, indeterminacy and the absence of tonality, much of the music of the second half of the 20th century began to develop. Stockhausen proposed the need to break with the music of the first half of the century, also including the ideas of sounds as such, since, as has already been said before, the development of instruments was rather related to musical systems that continued to belong to historical-traditional trends since the end of the 19th century. The search for new sounds, advances in the ways of composing and recording music, in addition to the use of musical instruments such as the theremin, Martenot waves or even the synthesizer, modified the way of creating music and experimenting with more technological resources, which It led to the use of computers and, more recently, artificial intelligence.

The need for more powerful computing systems accelerated with the invention of the transistor in 1947 and then the microchip in 1959. Ranchal (September 26, 2016) comments

that the first computer-generated music recording was made by Christopher Strachey in 1951 on a machine built by computer scientist Alan Turning, who is considered the father of computer science.

Musician and engineer Max Mathews began using computer coding to create digital sounds and then convert them to analog for amplification and playback, and around 1961 he achieved the first performance of a song: the traditional *Daisy Bell* "sung" entirely by a computer.

According to Miranda (2014), there are two approaches in the design of computer systems that generate music: artificial intelligence (AI) and algorithms. In the first approach, computers are basically programmed with already established materials, rules and scores with which they "learn" and generate new music; Aesthetically, it tends to produce *imitations* of the styles and shapes with which the AI systems were fed. In the case of the algorithmic approach, we work with the translation of data generated from non-musical models into musical language.

Musical compositions would begin to employ more advanced technologies, such as what Tod Machover proposed, for example, in his *Death and the Power: The Robots Opera* (2010). For this work, Machover, who is attached to the Media Lab at the Massachusetts Institute of Technology (MIT), developed *hyperinstruments*, acoustic-electronic hybrids that can be controlled remotely using special gloves. During the performance of the opera, the robot-instruments interacted with the singers, which generated a reflection on the way in which we adapt to machines and technology.

In the same vein, Golan Levin, in 2001, created the piece *Dialtones (A telesymphony)*, in which ringtones were sent to different people in the audience so that they would be activated during the musical performance. This highlights how immersive (and invasive) cell phone sounds have become in our own daily lives. Musicians such as William Ducworth and Eric Whitacre have taken advantage of the Internet as a way to make interactive and remote musical pieces, which was also widely used during confinement due to the covid-19 pandemic, where it was possible to carry out performances via Zoom, with each interpreter from their location.

A precedent for this was the piece *Sleep* (2000) by Whitacre, for virtual choir, where the singers, from different parts of the world, sent their participation over the Internet and the composer edited it to create a video where they are apparently at the same time and space. Regarding the use of artificial intelligence, David Cope, for example, developed an AI-based

composition system to analyze and compose music in the style of Bach, Mozart, Beethoven, Chopin, Mahler, among others. There are also *streaming* music reproduction systems such as the Music Genome Project that, based on Internet radio, Pandora (which is not available in Mexico), its search engine analyzes its catalog according to the listener's preferences. and offers recommendations to users based on AI algorithms.

The Mexican composer Enrico Chapela has also worked on works where technology is part of his poetics. On his album *Antagónica* (2007), for example, he recruited important Mexican musicians and recorded them separately and then edited and mixed everything on the computer. He thus created an orchestra that only exists in the digital realm, which he called the Silvestre Revueltas Virtual Orchestra. Using new technologies, on December 21, 2012, this composer premiered the work *Concerto for the End of the World* with the Dresden Symphony Orchestra and four soloists. This was transmitted through the Internet to the whole world, but, in addition to that, the soloists, Chapela himself, Gonzalo Ceja, Horacio Franco and Sara Curruchich Cúmez, were in Mexico while the orchestra and the conductor, José Arean. They played at the Saxon State Library, which exhibits the Dresden Codex, one of the most important and best-preserved Mayan documents.

The proposal is extremely interesting, because not only was it a tribute to the change in the Mayan time cycle, but the use of technology as a point of union between the Old and the New World is emblematic, in addition to the use of European symphonic instruments with pre-Hispanic musical instruments and the possibility that millions of people would witness the concert throughout the planet. The truth is that music has crossed the boundaries of what is merely auditory to become a much more complex sensory experience, from the development of sound sculpture to sound art, from which artists and musicians have also taken advantage of its potential.

One of the areas that is just beginning to be explored and that continues to be fertile ground for experimentation in musical and artistic hybridization is in the field of bioart, which emerged at the end of the nineties, but during the first decade of the 21st century it has had considerable impact and growth. This is a discipline where the borders of the visual, the sound, the technological and the biological intersect to build hybrid proposals whose discourses make statements about life, nature, ethics and other problems that concern human beings. The use of living organisms that, through computational algorithms and artificial intelligence, translate specific behaviors and properties, generate very interesting musical compositions.

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By 2017, the International Genetically Engineered Machine Street Bio Team published a musical work called *Biota Beats,* which was the result of the generation of music from the information obtained from bacteria that live in different parts of our body. The microorganisms were placed and cultured in a Petri dish and later in an incubator to allow them to grow; an image of the generated growth patterns was then taken and then a computer algorithm converted the visual patterns into acoustic-musical ones. The above can be seen and heard on its page, taking advantage of information and communication technologies to reach many more people.

Leslie García, together with the *Interespecifics* collective, has made several audiovisual pieces: a kind of hybridization between musical composition and soundscape, based on working with bacteria. An example of this is *Speculative Communications* (2017-2020), where, taking into account the study of the patterns that arise from the various morphologies of the *Paenibacillus bacteria,* those that were repetitive were investigated based on their behavior within biological tissues. According to García's (s. f) explanation, the information is passed to an AI algorithm that assigns a unique sound and visual gesture to achieve a self-generative musical composition that is modified with the movement and morphological changes of the bacteria. The algorithm learns and anticipates these changes and coevolves with the microorganism.

Gilberto Esparza, on the other hand, created *Bio-SoNot* (2015-2017), which is basically a bioelectroacoustic system that produces practically musical sounds from bacteria fed on contaminated water, which is obtained from rivers in different parts of the world where the piece has been presented. The system uses the electricity generated by the microorganisms that feed on the water sample and metabolize it. It also takes other biological parameters to create a kind of sound fingerprint, which will be unique depending on the biological characteristics of the river where said sample was taken. It is, therefore, a bioelectronic installation that produces a specific sound-musical landscape.

In addition to this, in recent years work has been done on the design of computers in which microchips that operate under electronic principles have been replaced by biological ones, such as slime molds, bacterial cultures, living tissues or chemical reaction fluids. This has given rise to what has been called unconventional computing systems, a term coined in 1994 by Christian S. Claude and John Casti.

From the behavior of a slime mold (*Physarum polycephalum*), Eduardo Reck Miranda developed the musical piece *Die Lebensfreude* (2012) for piano, violin, cello, flute, clarinet

and six channels of electronic sound. Physarum can be used *as* a biological computational substrate; It is a single cell with multiple nuclei that moves like a giant amoeba, which has been used in the study and design of biological computers due to its controllable behavior: it reacts in attraction for moisture and food, and in repulsion for sources of energy. light and salt.

The above can be controlled under specific conditions; there have been several studies on how *physarum chips (Phychips)* can solve logical, spatial and algebraic operations. The movement of intracellular components within the *Physarum 's body* produces electricity that can be measured with electrodes strategically placed on the surfaces where the slime is grown.

The problem is that its movement is extremely slow, but, based on the potential differences obtained when it was conditioned to colonize eight electrodes in Miranda's experiment, it was possible to convert them into short sound impulses by means of an additive granular synthesizer. This generates acoustic impulses referring to *granular sounds*, that is, they are composed of different partials or harmonics. To speed up the process, Miranda and his collaborators used equipment that simulates the behavior of Physarum in less time (in general terms, what takes weeks can be done in minutes) in a way that is very consistent with biological material.

From the movement of the *Physarum* when it colonized the different electrodes placed in the shape of a flower, the notes for each instrument and the rhythm of the piece were sequenced, from which the musical score of the work could be obtained in two movements: *Machina Vita* and *Machina est Finitum.* Physarum *polyphalum* gradually consumes the flower (the arrangement of electrodes where the nutrients were placed), so the piece ends when it is completely consumed. Furthermore, as part of the execution of the work, an animation simulating the behavior of the organism was projected, which gives an important audiovisual value to the piece.

Other type of biological computers are those based on bacteria, called *genetic chips*, according to Lobato (2021), who worked with this type of chip in his work *Pulcher aureus phylum* (2017). This hybrid piece intersects with musical composition, action art, installation and soundscape through the use of electronic and biological technologies. Using genetic treatment of *Escherichia bacteria colli* genetically modified to generate bioluminescence based on rhythmic patterns, like biological oscillators that depend on the shape of the containers where they were grown.

Something very interesting is that bacteria activate a communication mechanism called *crowd sensation*, which makes the entire community of bacteria shine in a synchronized manner. Furthermore, it is important to keep in mind that you are working with living, collective and perhaps social beings. So, to give it a post-anthropocentric approach, Lobato proposed scaling the synchronization phenomenon to a human level. To do this, he carried out an action where a group of people performed a meditation in which each attendee sang what they wanted, with or without lyrics and, mixed with them, he placed an incognito professional choir that sang a musical score composed by the author.

At some point in the action, the entire set of people synchronized in a similar way to the bacteria grown on the chips. The final part of the piece consisted of synthesizing the process of bacterial cultivation and the action of those attending the meditation. To do this, he used a totem plate with the geometric shapes in which the bacteria were grown, on which a *video-mapping* based on the behavior of the genetic chips was projected. The sound generated was obtained from eight recordings to which a fast Fourier transform was applied in order to analyze them spectrally. In this way, both synchronicity processes (bacterial and human) end up coexisting in that virtual space to achieve the final piece.

In short, the use of biotechnologies has come to modify paradigms in the world of science, art, music and even, we would dare to affirm, philosophy, as well as the way in which we relate as a society to nature. Bioartistic practices have increasingly expanded with sound art and musical composition, mixing the visual with the auditory through the use of biological material, which in turn acquires great poetic-artistic symbolic value.

Discussion

With everything stated in the preceding lines, it is clearly seen how the arts and music have appropriated not only technologies *per se*, but also their language, signs and elements to be used in current artistic discourses. In reality, there is no such extensive bibliography regarding the development of sound art, although there are some fundamental texts that have addressed its relationship with music, but they do not focus on the production of visual-musical hybridizations, where works can no longer be classified solely as music or visual-sound art, in which technologies are a fundamental part. In that sense, examples of these hybridizations have been presented that have blurred the boundaries between these disciplines.

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The truth is that it is still fertile ground in the creative and theoretical-analytical field; there are many lines to address, among them, the inter-technological relationships that have given rise to pieces where, for example, algorithms, artificial intelligence and biotechnologies are mixed, as well as visual elements during live musical performances. One of the most important texts that describes the development of sound art is that of Alan Litch (2019). The historical and descriptive analysis of the artistic pieces he creates is fundamental, but it abounds in technological or musical changes, as well as their influence on this discipline; however, it is interesting that it refers to the musical origin of many of the artists it mentions.

On the other hand, some texts on music from the 20th and 21st centuries only mention the use of digital, cybernetic technologies or artificial intelligence as part of the musical support, but do not delve too deeply into their discourse or their levels of significance. An example of this is Auner's book (2019), in which he highlights the importance of Machover's opera, regarding the chilling theme of a world populated with robots that carry the memories and personalities of their creators, something in which personalities like Elon Musk are working today.

Other important texts on artificial intelligence, biotechnologies and algorithms, some written by Eduardo Reck Miranda, talk about the fusion of music and technologies and, even though some of his musical works have a visual support, they do not delve into the artistic hybridization produced. One of the biggest limitations, and which opens the possibility for more lines of research, is the number of technological developments that are currently being carried out (these lines are written in the year 2023) and everything that will come after this. Therefore, it is difficult to find academic articles that contribute to research, beyond speculation.

Conclusions

The arts, both visual and musical, have always had some relationship with the sciences and technologies of their time; Musical instruments are tools or better, machines *strictu sensu.* The word *instrument* comes from the Latin *organum*[4], so it can be said that they are tools for producing music. Computers, electronics or other technologies, including biological ones, can also be designed to produce music, taking advantage of their potential to generate sounds never heard before, outside of traditional areas.

In the case of experimental music, as well as in concrete music, we worked with timbres and textures, beyond the canonical notions of rhythm, melody or harmony. Although it is true that between the 1950s and 1970s there was a real reluctance to make music using notions of tonality or conventional melodic-harmonic structures, from the 1980s onwards there was a return to neo-romantic and formal forms.

Much of today's music is not necessarily against traditional values but is used in conjunction with techniques and procedures from the avant-garde of the 20th century, generating richer and more complex musical discourses. Scientific-technological changes have played an important role in the development of these artistic and musical proposals, revealing reflections that raise the way in which we relate to nature, with other living beings and with ourselves; our dependence on the same technologies, the criticism of scientific univocality and what we understand by life and even intelligence. In addition, of the computational proposals that had a significant boom since the eighties -think, for example, of music for video games- today there are more powerful technologies, based on chemical processes or biological behaviors that will surely continue to be used, generating more complex applications in the scientific, artistic and musical fields.

Perhaps, never as now, does the premise made by Pratella become more evident, almost in prophetic terms, although with an important difference: for this composer, nature has been tamed by humans thanks to scientific and technological developments, but one of the fundamental aspects of the analyzed pieces is that, rather, they manifest, enhance, and make it visible through contemporary artistic and musical hybridizations.

In summary, in this writing a historical-analytical overview has been made of how art, music and technologies have blurred their borders to give rise to artistic hybridizations that expand the artistic-musical panorama of our days. This development has been gradual,

[4]Tool, instrument.

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not without controversy, especially through the use of digital tools, artificial intelligence, biotechnologies or living organisms. Through this analysis, we have begun to address the lack of studies on how sound art and music are intertwined through technology, opening their territories to the use of biotechnologies, in addition to living organisms that become part of their discourse.

Future lines of research

The previous exploration leads to at least two lines of research: on the one hand, a deeper analysis of visual-musical hybridizations that addresses ethical, aesthetic, technical aspects, among others, from various perspectives; on the other, a theoretical-creative reflection, generating innovative artistic projects that problematize the interaction between human beings, digital or biotechnological technologies, both in art and music. We scholars and practitioners of these disciplines cannot ignore these hybridizations that, although they are not new, continue to produce interesting proposals that give rise to deep and relevant discussions from the art itself.

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