Musical composition using metadata

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Abstract
This article explores the intersection of musical composition and digital technology by using metadata derived from natural phenomena to generate musical works. It examines the methodology employed and its application in cases where meteorological data, plant data, and brain activity data serve as sources of inspiration. These data are transformed into musical compositions that range from interactive sound installations to orchestral pieces. The article concludes by highlighting current perspectives of this work in collaboration with other scientific disciplines.

Keywords
musical transcoding, mimesis, post-digital, contemporary music, environmental art

1. Introduction

Current artistic creations and creative processes reflect a "post-digital" society (Cascone, 2020), marked by the omnipresence of digital technology (Gohon & Parent, 2022) and shaped by ecological challenges. This is evident in the rise of digital and environmental art (Solomos, 2023). In contemporary music composition, we see the evolution of computer music, where this machine becomes the "metamedium" (Manovich, 2013), expanding compositional possibilities and as a medium of generative, interactive, and/or immersive music works.

Many contemporary music works aim to raise ecological awareness by creating soundscapes from field recordings or composing music inspired by the mimesis of nature's forms and behaviors (Landazuri, 2012). To achieve these musical representations, musical transcoding methods (Elipe-Gimeno & de Paiva Santana, 2022) are used to extract data from natural phenomena to model "datascapes" (Schiuma & Carlucci, 2018), where metadata structures the musical discourse. This multimodal coding aligns extra-musical parameters with musical language. This process, which puts us in active relation with a living reality through sound, enables us to apprehend this model derived from nature through an aesthetic experience, which, by evoking the sensible, awakens a new perception of this dynamic form and provides innovative combinations and arrangements to the compositional material that reflect the complexity and interconnectivity of the natural world.

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This article will discuss research-creation works based on models derived from natural phenomena as a foundation for creating compositions, including meteorological data, plant data, and brain activity data.

2. Theoretical foundations

The concept of a model in musical composition refers to pre-existing structures used as a foundation to build a musical piece. For Iannis Xenakis, who used physics and mathematics to build his compositional system, models materialize thought movements and support artistic creation. He considered sounds and music as means to express laws and structures through their materialization in symbolic music, which he termed “stochastic” (Xenakis, 1963). François Bernard Mâche sees the world as a visible “analogon” of music, using models to eliminate contingent elements of reality and giving new appearances and functions to the revealed substance, conferring aesthetic meaning to reality through art (Mâche, 2001). Philippe Leroux considers models central to creating pitch, harmony, and rhythm, describing acts of imitation as “mimesis”, influenced by Marcel Jousse’s “intussusception”, where external actions are absorbed and replicated to integrate. Leroux also explores the notion of the model of the model (the mise en abyme of the model), referring to a feedback process where each analyzed and worked model potentially becomes a new model for a new creation (Leroux, 2008).

Composers translate models—such as the rhythm of the waves, the noise of the city, a mathematical formula, or the growth pattern of a tree—using their imagination, calculations, musical skills, and established composition codes. Technological advancements have enhaced these resources, enabling new ways to integrate musical or extra-musical sound models into the creative process. Stimulated by a kind of “synesthetic” thinking, “musical transcoding”, as by Elipe-Gimeno, J. and de Paiva Santana, involves transferring patterns, forms, or structures from one system to the musical code, taking advantage of the multimodal aspect of digital coding (Elipe-Gimeno & de Paiva Santana, 2022).

In my research-creation work on contemporary musical composition and data art in a post-media world (Jagodzinski, 2021), I explored dynamic forms in nature to create musical compositions through musical transcoding. Firstly, these arrangements seem to repeat similar patterns, generating a sense of homogeneity and identity while constantly evolving. This perception resonated with neo-Confucian philosophical ideas, viewing *Li* as the immanent principle animating everything that exists, and Qi as the material force adopting various forms (Roy, 1988). Secondly, these forms have a characteristic temporal evolution profile, which inspired me to imagine different musical gestures from these models. This concept stems from Daniel Stern’s idea of “forms of vitality”, manifesting life through the interaction of movement, time, force, space and intention (Stern, 2010). Finally, these forms inspired me to raise awareness of nature, rediscover the imperceptible, and provide new perceptions of overlooked natural phenomena. This resonates with ecological art movements that foster awareness, education, and reconnection, leading a deeper understanding of the world around us and promoting resilience and eco-responsibility (Solomos, 2023).

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3. Methodology

To transform dynamic forms in nature into musical compositions, I developed a creative process in three stages: digitization, musical transcoding, and composition. The resulting compositions can serve as models for new works, creating a "mise en abyme" effect. This process progresses from live electronic performances, where the model is represented, to acoustic instrumental compositions, where the model becomes an abstraction, retaining its essence in a new aesthetic context.

3.1. Digitization

The initial stage involves data collection using online databases, specially designed capture systems, or commercially available capture systems.

For meteorology, the *Dark Sky API* service was initially utilized to provide real-time weather data, forecasts and historical weather information. Data calls were made via *Max*, specifying location coordinates and the type of data required, and stored for subsequent extraction. The information was structured and saved locally using *Max* tools. After the discontinuation of *Dark Sky API*, *OpenWeatherMap*[2] was utilized, offering historical data in JSON and CSV formats.

For plant data, Arduino microcontrollers equipped with sensors measured parameters such as conductivity, humidity, and temperature during live performances. For more accurate, long-term measurements, the *PhytlSigns*[3] device was used to obtain electrical activity data. This device features a noise reduction system for precise data collection outside laboratory settings and a platform for visualizing data and estimating parameters like plant's drought level, stress, fungal infection and nutrient deficiency using AI tools. Recordings begin when the device is turned on and can be monitored on the company's platform. Data can be downloaded in HTML and CSV formats for further processing. Metadata files for older recordings are available for loading data into signal processing programs.

For brain activity, the *OpenBCI* EEG *Mark IV* headset with eight channels, paired with the *OpenBCI GUI* software, was utilized. This setup includes the OSC (Open Sound Control) protocol, allowing selection of data stream categories, port number, address and application of transmission. Data was sent to *Max* to perform real-time "musification" (McGee & Rogers, 2016), where the output is music, not mere sound, and used to produce a score. Subsequently, the data flow was sent to *Ableton Live* for audio output through virtual instruments and to *Unreal Engine* to modify parameters of objects in a 3D virtual environment. The brain data was saved to the computer as a CSV text file or BDF+ format, with no filters applied. Once the data is available and distributed on the computer, the processing stage begins to derive a musical outcome from the collected information.

3.2. Musical transcoding

The process of musical transcoding varied according to each model and the desired outcome. In live performances, pre-conceived schemes and an ensemble of synthesizers or virtual instruments were used to distribute metadata and reproduce the resulting sounds of the musical

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[2] OpenWeatherMap, Weather Data, 2024. URL: https://openweathermap.org.
[3] Vivent Biosignals. Vivent - Plant Electrophysiology, 2024. URL: https://vivent-biosignals.com.

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transcoding. Fragments of these live performances were saved for further use in instrumental acoustic compositions. This is the process described below.

Once the data is obtained, structured and stored digitally, the next step is to create a musical form using metadata. The descriptive metadata[4] provides information on data capture duration, origin, sampling frequency, sensors positions, and capture date and time, among other features. It is then mapped and scaled to the macro elements of the musical composition, such as total duration, number of sections, orchestration, spatialization, instrumental density, and dynamic range, forming a structural skeleton. This process creates empty containers, in the style of John Cage, each with different characteristics to be implemented in the music they contain.

These containers are filled with abstract data schemes that are then transcoded into musical notes. This data may include variations in plant microvolts, changes in precipitation intensity in millimeters per hour or the amplitude of alpha waves in the brain in microvolts. After filtering to normalize and reduce less significant data, it is mapped and scaled to pitch, duration, and intensity values.

Finally, by integrating both metadata and data, the resulting musical form and content are "printed" in a musical score. This structured information supports efficient workflow and versioning throughout the transcoding process, ensuring comprehensive documentation and traceability of the various data sources and their transformations, thereby enhancing the overall consistency and integrity of the compositional process.

3.3. Composition

After obtaining the first musical score, we proceed to an artisanal stage to prepare it for performance. We simplify rhythmic notation for readability while ensuring the same effect. We verify that notes match the instrument ranges and dynamics are within their technical capabilities. For wind instruments and vocals, we add breathing spaces, avoiding excessively long passages without breaks. This results in a second score arranged for acoustic performance.

Subsequently, a new version of the score is created with more direct intervention by the composer. First, the score is analyzed to understand the harmonic context, predominant melodic elements, and overall musical form. From there, several procedures are performed to refine and personalize the composition. Observed gestures are reinforced; for example, if a crescendo is produced by increasing the density of instruments, this gesture is enhanced with dynamic markings to ensure coherence. Harmonic arrangements are adjusted for better acoustic results, and notes may be added or removed to improve sonority. Melodies are fine-tuned, and dynamics are adjusted for greater musicality. To refine the score further, timbral details are added, including note relays, extended techniques with effects, and instrumental combinations to enrich the color of a passage. Additionally, specific melodic, rhythmic, or harmonic motifs can be developed to highlight and expand key elements. This process results in a third score, the final product of a dialogue between the outcomes of musical transcoding and the composer's artistic insights.

[4] Dublin Core Metadata Initiative, Metadata Basics, 2024. URL: https://www.dublincore.org/resources/metadata-basics/

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4. Results

This creative process using metadata, inspired by dynamic forms in nature, has comprised various stages, starting with the collection of information through online databases or the use of specially constructed or commercially available electronic devices. It then moved through the development of a method of musical transcoding, utilizing metadata and data to establish a system of relationships within a musical system, culminating in the creation of musical pieces first performed live with electronic media and then transformed into new instrumental compositions.

As mentioned before, this approach has been applied to three distinct models: meteorology, plants, and brain activity, each with a different dynamic profile. The resulting creations range from interactive installations and sound gardens to orchestral pieces. Below, we will discuss the series of "variations" of pieces that emerged from the same initial model in each case, in the mise en abyme of the model.

4.1. Meteorology

The first realization with this model was *Météorologie Sonore* (2019-2020)[5], a sound installation presented at the MAMAC museum in Nice, France. Real-time data on temperature, wind speed, precipitation intensity, and cloud cover from twenty-eight different cities worldwide were transformed into sound whenever variations in these meteorological parameters occurred. Each sound was assigned to a different type of synthesizer. The resulting music was a slow-evolving flow of harmonies with small variations. The audience could touch a screen to choose which continent to hear and listen to various combinations simultaneously.

Following this, a performance titled *#MétéoValberg* (2021)[6] was created for the *Controverses Numériques* festival organized by *Le Hublot* in Nice, France. This performance was on a VR social platform created with *Mozilla Hubs*, where my avatar symbolically conducted the forces of nature, with music resulting from meteorological variations interpreted by virtual instruments.

About ten minutes of this musical performance were recorded, which, after a composition process like the one described, led to the piece *Fréquence Terre* (2022)[7]. The piece was arranged for soprano, choir, and orchestra, with lyrics including the text of various data and metadata values used to compose the piece.

4.2. Plants

The work with plants began with the educational sound design and ecology awareness project, *L'Aqua Symphonie du Potager* (2020-2021), which consisted of creating a sound garden at the Louis Nucéra College in Nice, France. The system consisted of six Arduino circuits equipped with humidity, temperature, and conductivity sensors, connected by radio frequency to a central computer using NRF24L01 components, symbolizing the connection of nodes like

[5] R. Romay, Météorologie Sonore [Extrait 14 avril], 2020. URL: https://www.youtube.com/watch?v=DtNzOVhSn90.
[6] R. Romay, Le Tour du Monde en Réalité Mixte » III #meteovalberg- Controverse numérique #5 Le Hublot VR, 2021. URL: https://youtu.be/_HuL0_8pZ2c
[7] R. Romay, Weather based composition, Fréquence Terre, 2022. URL: https://youtu.be/_Hlvm_NoqJ8.

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branches of a tree. The information was then processed to trigger the production of notes whenever there were significant variations in these parameters.

This project led to the interactive installation-concert format *Green Méditation* (2021)[8], where the audience interacted with the plants through proximity and touch. It was showcased at various events, such as *La Nuit des Musées 2021* at the *Musée International d'Art Naif Anatole Jakovsky* and the *Festival Artifice Numérique* in 2021 at *Le 109*, in Nice, France. For these events, a more complex system of metadata interrelations was designed for live presentations. Subsequently, a recording of data from one of the performances was made, leading to the instrumental piece *Blooming* (2022)[9], arranged for an ensemble of nine from the *Conservatoire à Rayonnement Régional Pierre Cochereau.*

Currently, I am working with the *PhytlSigns* device to create new musical compositions from the electrical activity of plants and to train data models corresponding to different plant species in various environments and seasons. This work aims to facilitate the composition process based on these dynamic forms and to develop creative approaches that combine different models.

4.3. Brain activity

This project draws inspiration from Alvin Lucier's *Music for Solo Performer* (1965)[10], created in collaboration with scientist Edmond Dewan and first performed with the assistance of John Cage. My creative process with brain electrical activity, captured using an EEG headset, began with a VR installation titled *La Rose et les Étoiles* (2021-2022). This installation generated music and modified elements of a 3D environment based on the brain's electrical activity, using amplitude values of different brain waves across eight different channels. An audience member wearing an EEG headset modified the sound through biofeedback, controlling their relaxation and activity, while another participant navigated a VR environment affected by the same EEG data stream.

A second version of this work, titled *Flores hechas de Cielo/Flowers Made Out of Sky* (2022-2023)[11], named after a poem by Ana Maria Hernando, involved a composer reciting this poem and performing simple actions like closing the eyes, looking around and reciting. Data from the EEG was transmitted to *Wekinator* to identify patterns corresponding to these actions. results were sent to *Max* to trigger sound production in different synthesizers associated with various brain waves. A violinist interacted with this resulting sound, reading a graphic score. The performance's staging was again a basic VR environment that varied according to the received data.

5. Conclusions

Creating a musical system involves designing a holistic ensemble, a form of vitality that presents a deployment of forms, forces, and interactions, offering a way to experience time

[8] R. Romay, Music based on plants data, #RemixTaCulture, MAMAC, 2022. URL: https://youtu.be/JUzQznuW748.
[9] R. Romay, Plants data (humidity, temperature, and conductivity) to music score, "Blooming", 2022. URL: https://youtu.be/LelcuN9ev4c.
[10] Music for solo performer | IDIS, 2023. URL: https://proyectoidis.org/music-for-solo-performer/.
[11] R. Romay, Flowers Made out of Sky; violin, VR & EEG composer, 2023. URL: https://youtu.be/rxAMD7otgBE.

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through sound. The assistance of computers in the composition of musical works allows us to transform datascapes into musical universes. In these universes, the use of metadata in the musical transcoding process enables us to organize and interrelate materials and structure the musical form so that our digitized model becomes a dynamic and multimodal work, like music itself. Once the form is established, composing also involves assembling timbres, melodies, harmonies, rhythms, and dynamics to represent a coherent whole (Romay, 2023). The "containers" of the musical form, shaped by metadata that provides information about time, dynamic profile, and orchestration, are filled with data that will be embodied in musical notes, bringing dynamic forms to life as sound.

Incorporating these sources of inspiration into musical compositions allows us to discover unprecedented musical relationships, arrangements, and proportions, diversifying the compositional palette. At the same time, it provides a new perception of these initially extra-musical pieces of information, enabling us to experience and internalize them through the aesthetic experience. Working with models derived from nature allows us to create a new bond with our environment through musical creation, awakening our consciousness to something familiar, now endowed with a new dimension.

The current perspectives in my research-creation work in contemporary music include interdisciplinary work in art and health projects, linking music and neuroscience, and studying the effects of these nature-inspired musical experiences. Additionally, current collaborations with botanists and biophysicists aim to disseminate scientific knowledge and raise awareness of the plant world through immersive musical experiences accessible to the general public.

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