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# Collaborative Electroacoustic Music Composition on the Blockchain

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## ABSTRACT

*In the last decade, blockchain has been established as a transformative technology that is beginning to impact the key sectors of finance, health, energy, administration, and agriculture, among many others. In relation to arts, much of the current research focuses on the problems of the protection, dissemination, and monetization of art and music, which is created by conventional means. In this paper, we take a more experimental approach and propose a blockchain system for collaborative electroacoustic music composition that achieves consensus by measuring a contribution value. The main advantage of such an approach is having secure documentation that promotes trust and guarantees the integrity of the whole process while supporting a collaborative ecosystem for the creation of new music. We introduce a Proof of Creative Contribution (PoCC) consensus protocol, which measures a contribution value and assigns the composer with the highest value to record the composition data on the blockchain. In addition, we document a simulated compositional process that demonstrates the diversification of the block creator whose contributions have been well received by the network. The system supports a compositional process that is based on modular units, enabling multiple electroacoustic music pieces to be composed simultaneously, asynchronously, and non-linearly.*

## 1. INTRODUCTION

Collaborative composition of new music has been an enduring, yet marginalized practice through the developmental course of Western music. A variety of works, including operas, ballets, orchestral, chamber, and solo musical works, have been composed by a group of composers, predominantly by following the scheme of an organizer/producer who assigns different parts of the work to different composers. One notable example is the *Hexaméron* (1839) for solo piano, a set of six variations of a theme written by different composers and coordinated by Franz Liszt. In the chamber music repertoire, we find the *F.A.E. Sonata* (1853) collaboratively created by Schumann, Brahms, and Dietrich; and theorized to be a response to Wagner's ideas regarding artistry and community [1]. In recent times, that paradigm has been radically transformed by the advent of

electronic and digital technologies, systems that support more advanced interactions between composers.

The emerging blockchain technology is one of those very promising avenues for the exploration of collaborative art-making [2]. Blockchain is a technology that cryptographically records information in distributed databases through peer-to-peer computer networks [3]. A protocol defines a set of rules that allow the majority of the nodes in the network to achieve consensus and agree on the authenticity of the recorded data. Decentralization is the typical goal in all blockchain-based projects, and its important feature is the lack of any central authority that regulates the activity of the network.

In this paper, we propose a composition system for decentralized collaborative music creation that responds directly to current explorations of blockchain paradigms in art distribution, monetization, and creation. Blockchain technology in combination with the arts has so far supported specialized applications in the fields of copyright protection [4] and non-fungible tokens (NFT) [5]. These applications do not interfere directly with the creative process and offer novel solutions to the problems of protecting, disseminating, and monetizing art that is created by conventional means.

## 2. RELATED WORKS

The creative affordances and array of possibilities of the blockchain technology have seen the birth of a type of art that (1) either reflects the nature of encrypted distributed databases or (2) art that uses blockchain as a specific tool for creative endeavors [6]. The first type can be seen in a practice known as 'Cryptograffiti', or images stored as digital detritus on the blockchain, similar to attached messages of apparently redundant data value [7]. The second type, also known as 'Crypto Art' are pieces specifically made for the blockchain medium, including adapting to limitations of storage and distribution practices [8]. There are already efforts documenting a wide range of approaches that artists are taking to use and/or re-purpose the blockchain in their creative work [9].

Regarding the direct application of Blockchain in musical creation (collaborative or not), the number of studies and projects is, however, remarkably small. Some recent examples include the Decentralized Autonomous Organization (DAO) Holly+ by American composer Holly Herndon [10], 'Rhythm Dungeon', a decentralized gamified experience that uses the blockchain to provide asynchronous multiuser interactions [11], and the Kepler Concordia, a NIME project initially structured to facilitate a musical "community that functions as a creative economy and a collaborative ecosystem" using a blockchain-based

paradigm [12].

Outside academia, the company 'Musical Blockchain' claims to have developed "the world's first creative approach to blockchain as a solution for melodic sequence composition" in a self-published, non-peer-reviewed whitepaper [13]. Although the methods described to achieve such results are obscure, they seem to rely on a combination of AI-powered improvisation and machine learning applied to data extracted through music information retrieval.

In this study, we also built upon the conclusions of collaborative projects that utilize a client-server architecture. In terms of adopting a multiphase creative approach, we drew inspiration from the model proposed by Biasutti and Concina [14] in their pilot study that involved a composition framework with both synchronous and asynchronous components. Similarly, we noted web-based work in the field involving a 'reactive' approach to collaborative composition, which gives freedom to composers to intervene in existing contributions by other users or simply start their own pieces inside the same framework [15]. Finally, we acknowledge recent efforts toward the implementation of collaborative creative systems on the blockchain [16].

### 3. ELECTROACOUSTIC MUSIC COMPOSITION ON THE BLOCKCHAIN: PROJECT DESCRIPTION

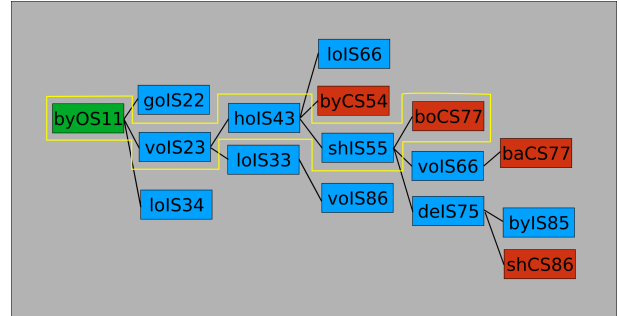
A blockchain-based system for composition involves a series of challenges. First, elaborating on a preplanned form is not possible. Nonlinearity is also a factor to consider: the composition can expand in multiple ways, and there is little chance of anticipating the result. The end result might resemble a 'Moment Form': "self-contained (quasi-)independent section, set off from other sections by discontinuities" [17]. In this section, we summarize the formal decisions taken to guarantee a degree of aesthetic cohesiveness while adhering to our distributed approach to the creation of new music on the blockchain.

#### 3.1 Collaboration model

The basic principle in our approach is the discretization of the collaborative composition process with well-defined units-modules which are referred to as contributions. Composers can make two types of contributions, (1) segment and (2) revision.

We define a segment as any kind of tentative musical idea that is composed with a DAW program and has a duration between 1 and 60 seconds. Three types of segments are possible: Opening Segment (OS), Intermediary Segment (IS), and Closing Segment (CS). An Opening Segment can be linked by subsequent segments only from the right, or in other words, it may be used only at the beginning of a composition. An Intermediary Segment can be linked from both left and right, meaning that it can arbitrarily continue any other segment anteriorly or posteriorly. A Closing Segment can serve only as the coda of the composition, being able to be linked only from the left. We also define a Root Segment (RS), a segment that can be OS, IS, or CS, that has been submitted without any links to other segments. An RS serves as an initial segment from which a new composition nexus can eventually be developed. In terms of the meta-structure, a composition *nexus* is the way we call

the emergent arborescent structure that contains all the interlinked segments. The composers have the flexibility to compose any type of segments and attach them to already formed composition nexuses or begin a new one with an RS.



**Figure 1.** A fully developed composition nexus. The green boxes represent the opening segment contributions, cyan the intermediate segment contributions, and red the closing segment contributions. The yellow contour highlights one of the four preliminary compositions that have been formed in this nexus.

A preliminary composition is a path from an OS to a CS within a composition nexus. Preliminary compositions can be isolated from the nexuses and can be revised numerous times by multiple composers. A revision contribution is a modification of the compositional parameters of a tentative composition and can include editing of the audio clips, insertion of sound effects, adjustment of gains, and overall mixing. All alterations have to be commented on inside the DAW file. A revision contribution can be submitted as open (further revisions can be attempted by other composers) or final (no further revisions are allowed). A revision contribution that is final is endorsed as a final composition and is available for public listening.

#### 3.2 Technical features

Our proposed system is structured in three layers. The first layer is a rigid blockchain structure that chronologically tracks all contributions by composers and serves as the archive of the collaboration process. In the second layer, nexuses of interconnected musical ideas are created in a dynamic, non-linear, asynchronous, and open-ended fashion, leading to the formation of preliminary compositions. In the third layer, preliminary compositions are repeatedly revised by multiple composers to become finalized compositions.

The first layer consists of the blockchain structure in combination with a P2P database that contains the Audio Workstation (DAW) and audio files. Each block contains an index, a timestamp, the hash of the previous block, a hash of the composition data, and a hash of all the data structures within the block (Figure 2).

In the second layer, which is called the composition field, the main collaborative activity occurs. An interactive graphical interface allows the composers to view, listen to, and download the data package of the validated segments. All evolved nexuses are distinct and clearly visible to facilitate the process of finding the appropriate spot for composers to invest their creativity.

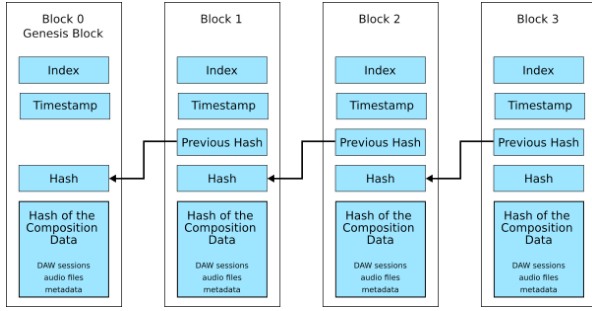


Figure 2. Scheme of the blockchain data structure.

The third layer functions in a similar fashion as the second layer. Designated as the revision field, the composers are able to see, listen to, and download the data package of the validated revisions. Any preliminary compositions that are formed in the previous layer, will be automatically shown in that layer in order to initiate its revision phase.

### 3.3 Consensus protocol

Various Proof of X (Proof of something) consensus protocols have been proposed and elaborated in recent years with the goal of finding solutions and optimizing several parameters regarding the general problem of distributed trust [18]. In our case, several of those proposed parameters are not important for the successful conduct of the project. For example, almost all of the recently developed protocols aim at fast block validation rates in order to cover the demand of high transaction volumes. The practice of electroacoustic music composition typically takes place on long-time scales, so there is no requirement for a rapid block validation process.

The primary goal of our proposed Proof of Creative Contribution (PoCC) protocol is the creation of a diversified and fair validation process based on the compositional effort that the composers put into the system. We established a set of explicit rules that composers have to follow in this protocol: (1) a submitted contribution is linked to only one other contribution, (2) only contributions that are Root Segments do not provide a link, and (3) two contributions by the same composer cannot be linked.

All newly submitted contributions are collected in a pool, waiting to be validated. When an exact amount (e.g. 10) of contributions are accumulated into the pool, one of the composers will be proclaimed as the block creator according to the consensus protocol. The block creator-leader is responsible for recording all the segments from the pool to the blockchain, and broadcasting the updated composition field to the network. This cycle, which is referred to as *epoch*, is going to be repeated indefinitely, allowing multiple compositions to be evolved simultaneously.

We introduce a pointing system that measures the contribution value for each composer and assigns the composer with the highest value to record the composition data on the blockchain. In every epoch, the composer with the highest contribution value becomes the validator-leader. The mechanism which is described below favors the composers who have put compositional effort into their contributions and the community has appreciated this effort by continuing their segments. Those composers who are selected as

block validators will have the motivation to keep the process fair and transparent since their artistic work is at stake.

The contribution values for all the composers are calculated with the following mechanism: A new contribution (any type of segment or revision) will give 1 point to its composer. A segment that is continued and linked on any nexus will give 2 points to its composer. All segments which can be linked in any possible way, within the nexus, to the submitted segment will generate some value according to a negative exponent formula. We prefer the formula  $2/3^{n-1}$  over  $1/2^{n-1}$ , where  $n$  is the link depth because it is more likely to create sums that are not equal so that ties are not going to occur frequently. A revision contribution will generate value to all the composers whose segments constitute the preliminary composition that is being revised.

### 3.4 Challenges of the protocol

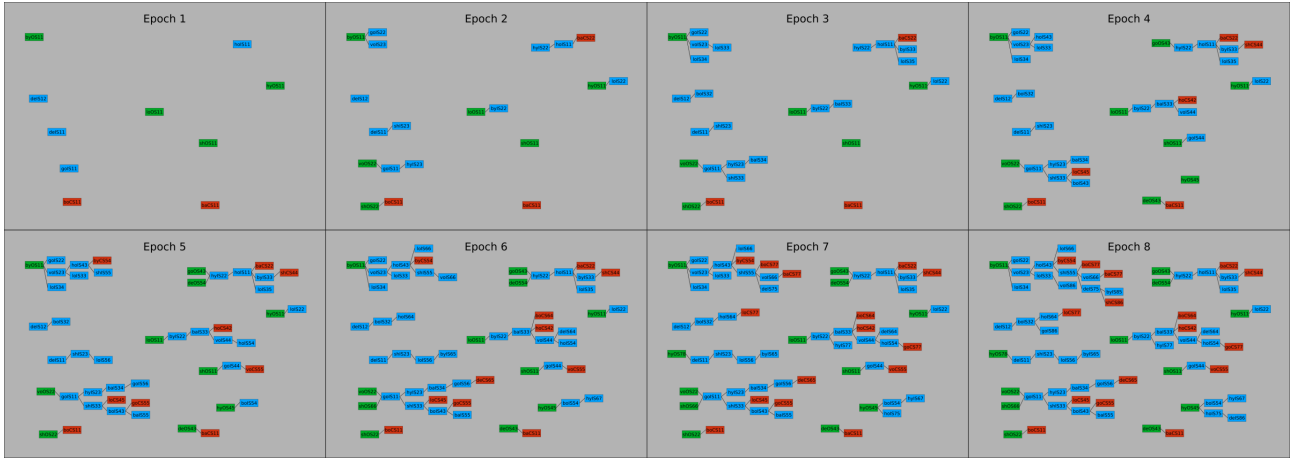
The proposed consensus protocol is vulnerable to a number of security flaws, such as Sybil attacks [19], Denial of Service (DDoS) [20] and hard forking [21]. A public-permissioned (publicly read, privately written) version of the blockchain would potentially deal with those issues but we aim for a permissionless blockchain that will be able to sustain the experimental practice of electroacoustic music. Therefore, we suggest a hybrid version of the presented consensus protocol that could incorporate Proof of Work or other forms of consensus. For example, in order to prevent submissions from fake addresses, the nodes will have to invest some computational resources by generating a nonce and submitting it within their contributions so that the overall hash has a certain amount of leading zeros. In the case of scaling up the project, such a development will potentially introduce problems that are well known in the blockchain research community such as 51 percent attacks [22] and computational overhead [23]. These considerations will be the focus of our future research.

## 4. SIMULATION STUDY

We conducted a simulation study with 2 human composers over the course of 4 months in order to assess the creative potential of the collaborative model, as well as to test the properties of the consensus protocol.

The initial phase of this process, was the creation of 10 pseudonyms inspired by 5 male and 5 female historically prominent figures (byron, shelley, goguen, basho, voltaire, hypatia, lovelace, hopper, boulanger, derbyshire). Both of the composers involved had to assume one of these identities before submitting a new segment. The 'multiple personalities' could be associated with a trend not uncommon in electronic music artists that often create and release works with multiple aliases, usually done to experiment with different styles without repercussion in their main careers. Similarly, it could be seen as an autoethnographic experiment of sorts: branching blockchain segments with different aliases and aesthetic attributes related to their perceived personalities.

In terms of sound production, the process simulation required the compositional constraint of avoiding using external plugins and commercial effects. Rather than an impediment, we considered that obtaining variety with a lim-



**Figure 3.** Progression of the composition field in our simulated process. Four prospering and three underdeveloped nexuses have been formed in the 8th epoch, each through a different evolutionary path. Some nexuses contain multiple tentative compositions.

ited set of tools could potentially push creativity forward, and help with cohesiveness. These constraints were based on the assumption of a technical formalization that would facilitate the recording of the compositional data on the blockchain. In the current version of the project, we intended to record only the hash of the compositional data on the blockchain, thus there are not any limitations on the software that is being used, open-source or proprietary.

Another aspect that could potentially help with obtaining a cohesive result was the use of a common database of sounds, which is also a compositional parameter that has a significant impact on the aesthetic language of the composed music. We utilized the database of the CECIA project, a previous collaborative project with a pool of 25 recordings created by the composers Panayiotis Kokoras, Mariam Gviniashvili, Juan Carlos Vasquez, Martyna Kosecka and Erik Nyström [24]. Given our past involvement in the CECIA project, we decided for practical reasons to re-utilize the database in a Blockchain context to further exploit its creative potential. Using and re-using databases has precedents in the EA music field, such as Henri Pousseur’s ‘Scambi’ [25] and John Cage’s ‘Williams Mix’ [26], a practice that stems from the musical form experiments with ‘The Open Work’ [27].

With this model, we achieved 8 epochs (Figure 3) and composed 71 segments with an average duration of 10.3 seconds. Four prospering and three underdeveloped nexuses were formed, including 20 preliminary compositions in total. The average duration of those preliminary compositions was 46.3 seconds. We notice that this model affords short compositions but with the passing of many more epochs, longer pieces may eventually be brought about. Additionally, we did not employ any revisions, which had the effect of many of those preliminary compositions sounding somewhat fractured, with most transitions from segment to segment being sonically perceivable.

In each epoch, there was a single pseudo-composer who received the highest contribution value and was selected as the leader who records the data on the blockchain. As seen in Figure 4, a fair distribution of the highest contribution value among the pseudo-composers is observed, a result that supports the diversification property of our

PoCC protocol. During the process of composition, we did not track the contribution values of the pseudo-composer and assigned the pseudonyms according to the aesthetic attributes.

Conducting this simulation study provided valuable insights towards a potential large-scale methodology, in which a feedback cycle between the design of the collaborative model, technical implementation, and compositional practice, leads the evolution of the project to a mature state. During the simulation, we realized that some composed segments draw inspiration or/and used concrete material from other segments although they were not directly connected. In a future developmental cycle, we would like to include further links that are conceptual in nature. This feature is proposed to function in a similar fashion as the way citations occur in scholarly works, in this case generating additional contribution value to the composers who are ‘cited’.

## 5. DISCUSSION

This project has a number of technical, political, and philosophical ramifications which will be analyzed in future work. We would like to discuss briefly some of them here.

From a philosophical standpoint, this project criticizes the individualist Kantian notion of artistic genius that drives the creation of western art and music since the beginning of modernity [28]. Following the alternative views on authorship posed by post-modern thinkers such as Barthes [29] and Foucault [30], we envision kinds of music that are made from transindividual perspectives [31]. Although we begin this project with an emphasis on electroacoustic music, we are interested in witnessing a flourishing of novel and established musical aesthetics that are afforded by the model we are proposing.

This project also adheres to an open-source framework in which the communities of electroacoustic and computer music co-develop the collaboration model, the technical infrastructure, the artistic practice, and finally the dissemination of its artifacts. The models and technologies presented in this paper are meant to be revised, altered, and further developed while acting as a pivot for the investigation of



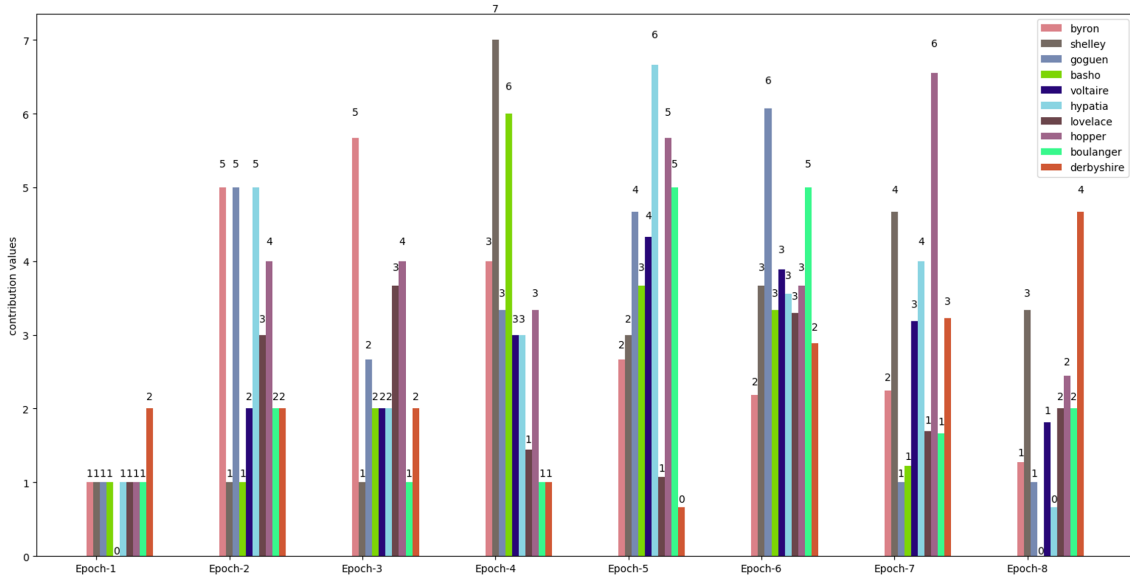


Figure 4. The accumulated contribution values in each epoch for all the pseudo-composers.

experimental blockchain applications for new music creation.

It is equally important to acknowledge that Blockchain technology is ethically and politically prone to controversy [32], and we feel the need to include a community-wide discussion of its implications in our framework. While most of the blockchain projects endorse a neo-libertarian ideology [33], we think of the technology as a tool with the potential of achieving pertinent governance of the commons. In that regard, our project aims for some of the ideals heralded by the P2P foundation [34]. Specifically, our design is intended to be aligned with the principles of (1) trust-scaling technologies for integration of human relationships, (2) replacement of competitive game incentives for cooperative mechanics, and (3) diminishing extractive activities in lieu of generative dynamics.

Furthermore, we have the utopian vision of creating a communal economy by introducing at a later point a token or a mutual credit currency [35], that would correlate with the measured contribution value. Such an ecosystem would be democratic, diverse, inclusive, equitable, decentrally governed, and could ideally achieve a degree of sovereignty, allowing new music to be created reflecting the post-capitalist political economy of distributed ledgers (aka. 'systems that operate in an environment with no central authority' [36]). For that end, we will consider alternative distributed ledger technologies such as holochain [37] in our future research.

In a similar vein, we need to also address the important issue of off-chain governance [38]. While on-chain governance refers to the rules that are coded and enforced by the blockchain, off-chain governance is the decision-making process that determines the capabilities of the collaborative model, rules of the protocol, and the implementation of the technology. A body that will be able to address those issues, and handle any emergencies and states of exception while supporting the above-mentioned ideals, is also a key component of this project. Given the international scope of the ICMA, we believe that the International Computer

Music Conference is the best place to begin this endeavor.

## 6. CONCLUSIONS

In this paper, we introduced a protocol for the collaborative creation of electroacoustic music on the blockchain, and validated the methodology via a simulated compositional process that provided valuable takeaways for the implementation of a future large-scale model. Given that both the technical and conceptual ramifications of integrating blockchain paradigms in EA music are significant, we consider the present study an initial attempt to reflect and provide insights into alternatives for composition that reflect some of the contemporary concerns of present-day society. As mentioned before, the involvement of the community in this process is crucial, for which we extend our invitation to everyone interested to contribute to the discussion.

## Acknowledgments

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