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# Ecosystemic Music:
# Building systems for improvisation and musical performance using algorithmic composition and AI

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## Abstract

Ecosystemic music is a framing of musical systems based on natural ecosystems. Just as energy moves through ecosystems, so too does sound and data move through musical systems. By making this connection between musical systems and ecosystems explicit, I examine how the study of ecosystems can inform the creative and technical choices in the design of these systems. The role of AI in ecosystemic works is twofold: first to enable data and sound processing at a larger scale than has been possible, and second to provide a method of decision making that is distinct from human interpretation. These systems fundamentally propose a method of improvising or performing with AI systems. I examine these dynamics through two approaches to developing systems for co-creativity using algorithmic composition and AI. The first approach is the use of algorithmic systems for recording analysis and playback that respond to real-time inputs such as performer audio or listener presence. The second is the use of autoencoders, either in the preparation or performance stage, to facilitate real-time interaction with data sets and a corpus of recordings.

**Keywords**: Algorithmic Music, AI and Music, Ecosystems

## 1. Introduction

The ecosystem concept provides both a practical framework for designing musical systems as well as highlighting philosophical questions that arise in the design of those systems. An ecosystem—more than the sum of its parts—is a system within larger environments within which energy moves along pathways via functions such as predation, decomposition, and consumption (Golley, 1993; Tansley, 1935). In an ecosystem, the action of any constituent member has rippling effects on other elements of the system. Ecosystemic music takes this as the fundamental starting point for the design of systems.

The motivation behind framing musical systems as ecosystemic transcends a convenient framing for discussion; the fundamental goal is to provide a model of musical thinking that allows for the use of algorithmic and AI tools that elevate the tools to the role of creative and improvisational partners while still maintaining the creativity and autonomy of composers and performers. That is, there is a foundational framing around and focus on improvising with these systems. Lewis' (2000) account of Voyager provides a precedent for understanding human-computer improvisation as a negotiation among participants with distinct musical behaviors. And Haraway's (2016) concept of sympoiesis, or making-with, provides a broader ecological framework for considering how creative possibilities emerge through relationships. In the systems I discuss here, "improvising-with" emphasizes that performers' choices and computational responses are mutually interactive.

I specify "system" here to clarify that the focus is on musical works that unfold over time but are non-linear in their construction. While linear compositions can certainly be ecosystemic or explore themes related to ecosystems, I am focusing here on composing interaction in a manner similar to that laid out by Di Scipio (2003). Composing interaction means a focus on defining the interactions of constituent parts of the system, essentially, defining how energy will transfer through a system. This focus of Di Scipio on defining interaction maps well onto considering how the design of ecosystems can inform musical system design.

The systems that I discuss in this paper are broadly digital systems that employ AI or algorithms to analyze sound (both pre-recorded and live), manage playback and synthesis of audio, and employ electronic processing in a responsive manner. These systems are both used alongside acoustic instruments and can be used alone to create electronic performances or installations.

## 2. Ecosystem Concept

An ecosystem is a complex system of varying size in which energy is transferred via multitudinous pathways between organisms such as bacteria, plant life, and mammals and their physical environment. Arthur Tansley's (1935) concept of the ecosystem, as later expanded by Eugene Odum (1969), provides a frame through which to understand and study conglomerations of organisms and their environment as systems.

Within the ecosystem, energy moves via a variety of processes. Different organisms function at different trophic levels; organisms at higher trophic levels consume organisms at lower trophic levels. For instance, trophic level one contains the primary producers such as plants. The second trophic level contains the herbivores that only eat plants, and so on (Golley, 1993). From a musical perspective, this framing is helpful for the design of systems in that not every sound source or sub-system need have the same impact on the final sound. Some systems, such as a granulation engine, might be more affected by the output of other sub-systems relative to their own impact.

In addition to energy flow over small timescales, long-term transformation of ecosystems also provides a useful model for composing a narrative arc over the realization of a system. Specifically, the concepts of succession and equilibrium are useful frames. Succession is the idea that ecosystems move through a variety of states—particularly after a destructive event such as a fire. In classical accounts of ecosystem development, dynamic equilibrium describes a relatively stable overall state maintained through ongoing processes (Odum, 1969; Tansley, 1935). Succession is useful for composing interaction: musical systems under this model both have probabilities to move from one state to another, and the change from one state may be more immediate than a continuous interpolation. Equilibrium is useful as a way of understanding a possible goal state of a musical system. By providing goal states via algorithms, responsive digital systems can create vastly different sonic results and move between them either through interpolation or via state changes.

### 2.1. Philosophical Implications of Ecosystems in Musical Systems

The development of the ecosystem concept highlighted shortcomings in the scientific community's understanding of our environment, but throughout its development, multiple issues emerged around the study of ecosystems. Some of these issues provide a frame through which to examine the composition of musical systems. Specifically, the debate between bottom-

up and top-down approaches and the issue of defining ecosystem borders are both illustrative in this case.

The debate between bottom-up versus top-down research in ecosystems reduces down to whether it is more important to understand the individual members of an ecosystem and thus to conclude the output of the whole from the addition of its constituent members, or vice versa by studying the system as a whole and then working down to the contributions of individual members. The answer is of course that both have value, but this question is quite insightful for the sound design of a system. It is not sufficient to decide on individual sonic details and to focus only on those minutiae, but it is just as insufficient to only consider the system as a whole and not consider the small-scale relationships.

Defining the borders of an ecosystem is inherently difficult. Some ecosystems have clearer boundaries, such as lakes, but the borders of ecosystems are often porous, with organisms and energy crossing the boundary (as far as there is one) in both directions. Again, this provides an interesting frame for considering the edges of systems in a musical context. Input microphones and computer programs can provide a more solid border that insulates intended musical sound from ambient noise, but these barriers are always permeable. Further, this exclusion warrants deeper examination as to whether it is even desired in every case.

## 2.2. The Role of AI in Ecosystemic Music

A central question then is what is the role of AI in enabling these systems? The general systems described thus far rely on interaction between constituent parts. The two clearest roles for AI use in these systems are as a tool to expand their size and as a decision-making agent that provides contrast with human performers.

AI is useful in order to define relations and interactions across multiple systems and to facilitate the necessary workload of analyzing large chunks of audio and data in real time (Borg et al., 2022). Algorithms can control the response of a system to a given stimulus, and through devices such as Markov chains create complex reactions to varied stimuli (Pachet, 2003). Learned models can expand this capability through the use of variational autoencoders for audio synthesis (Caillon & Esling, 2021). Such systems can process inputs not encountered during training, although meaningful responses to unfamiliar inputs are not guaranteed. This is especially useful in an improvisation context where it may be impractical to predict every possible sound the model might encounter in performance.

These systems also provide a response trajectory that can differ from both human interpretation and explicitly programmed responses (Borg et al., 2022; Pachet, 2003). In a system where actions cause responses as mediated by probabilities and interpretation, a system capable of managing large amounts of data and making decisions based on that can expand the scope and capability of these systems. Further, AI can provide a middle ground between the interpretation of a human performer and explicitly specified decision rules. AI systems are themselves algorithmic, and probabilistic models can support varied responses.

Similar to the centrality of the ecosystem framing to the design of musical systems, this proposed use of AI is not incidental. The central focus here is on creating a pathway for improvising-with these systems; for building systems that allow for co-creation that still elevates the creativity of the human performer. The use of AI in these systems is not designed to replace human creativity, but to provide further avenues for continuing it.

# 3. Ecosystemic Music

To examine ecosystemic music in practice, I will analyze two works that use AI in service of creating musical systems. Both of these use AI in fundamentally different ways. *Resonance Ecology* principally uses AI as a large systems enabler, providing an analysis and connection engine across disparate subsystems. *Sonifying the Arctic* uses AI to analyze large sets of data with different sampling periods and across different temporal spans (Gerard et al., 2024).

## 3.1. Resonance Ecology

Resonance Ecology is an open-duration work written for open instrumentation. The piece combines field recordings and passive acoustic monitoring with live performers and reactive visuals. The central goal of the piece is to mirror the design of an ecosystem through the construction of a musical system.

A Max patch is used as the central hub of the system: the system analyzes sound being performed live and recorded sound being played back through the system. It uses the results of the analysis to change processing decisions, trigger video or audio playback, and steer the internal statistical model. The score the performers are given is non-linear and non-determinative with instructions that call on them to listen and respond to their surroundings. Through this listening, performers can develop a situated understanding of the relationships among their own actions, the computational responses, and the surrounding sound. Feld's (2015) acoustemology provides a frame for considering how that understanding emerges during performance. Through this setup, every participant in the sonic fabric of the system has an influence on every part. Just as in a real ecosystem, the connections are not always easily teased out or determinative.

The role of the computer system here is as facilitator. In order for the system to respond to inputs, it must analyze the sounds being sent through the system. In this particular case, it uses frequency and amplitude, as well as a selection of spectral descriptors from the zsa.descriptors package (Malt & Jourdan, 2008). These descriptors then drive a probability model that adapts to the input received to try to determine the current sonic state of the piece and to trigger sound playback, processing, and video based on that analysis. The unpredictability of the system emerges from the combination of human performers with the algorithmic decision-making system. The central Max patch incorporates randomness, but the variety of realizations possible in performance is much greater than a system that only used one or the other. Of course, variety is not the only goal, the central idea is to create a system where responses in one part of the sound system influence other parts. This is only possible by using a system that can manage the large amount of inputs and processing necessary. These systems were possible before the advent of AI, and in fact, *Resonance Ecology* is more accurately characterized as a probabilistic model as opposed to a use of generative AI, but it is illustrative for one possible use of AI systems in music.

## 3.2. Sonifying the Arctic

Sonifying the Arctic is a system for sonifying data and recordings from passive acoustic monitoring and weather stations; it can be realized in live performance, an installation format, or through an interactive user interface. The system builds on the autoencoder-based imputation

approach proposed by Macias et al. (2021) for estimating missing entries in clinical datasets. We adapted this for use in our project by combining passive acoustic monitoring (PAM) recordings across Iceland's National Parks with weather station data. The weather station data covers considerably more time than the PAM recordings, so the autoencoder allows for a speculative value to be imputed for times without recordings (Gerard et al., 2024). The data from this system then can be fed into a sonification system that uses synthesis and granulation engines to sonify the data. The system also uses actual recordings as the fundamental sound source.

The central idea here is that AI allows for analysis and speculative sonification that would not be possible without the use of autoencoders and independent models. Importantly, the results of the model are not directly sonified, but first mediated through translation layers. The speed of the AI model allows for real-time interaction with the system. Either in performance, or as a listener interacting directly with the sonification engine. In this specific system, one goal was to make data tangible to both researchers and the public. The large capability of an autoencoder system to process data with little to no labeling opens the door to systems that can connect large datasets and recording archives, potentially even in a real-time improvisation context.

## 4. Conclusion and Future Directions

As AI continues developing, it is imperative to consider models of interaction that preserve human creativity and open pathways for performing with these systems. I do not argue that ecosystemic music is the answer to how to manage AI systems, but I do posit that thinking of AI as a co-creator is a useful frame as we move into the next stage of AI use, particularly in the arts.

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