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Butterfly Effects: Synthesis, Emergence and Transduction

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Abstract
This paper describes a music project in progress that attempts to model monarch butterfly behaviors and migration patterns in sound, using the programming language SuperCollider. The goal is to achieve a dynamically generated composition that combines core elements into a complex system, describing patterns of emergence and survival. It is a transduction of living systems, data streams, and digital sound. Generative sound synthesis becomes both a metaphor for life processes, and a means of destabilizing culturally constructed notions of nature.

Introduction
My current music compositions focus on rendering information from scientific research (including ecology, immunology, and economics) in sound. While some of these projects involve writing instructional scores to be performed by improvising musicians, I am particularly interested in using dynamically generated computer music to model living systems. Along these lines, I am beginning a project using the audio synthesis programming language SuperCollider to model behaviors and migration patterns of monarch butterflies. My goal is to mobilize research on monarch ecology to create generative music that articulates themes of adversity, resilience, individual activity and group survival.

Monarch Migration
Approximately 250 million monarch butterflies fly up to 2,500 miles each fall from Canada and North America to Mexico, and many more along the coast of California. A northward migration occurs each spring. This migration path has existed for some 40 million years, although each migrating generation is a few generations younger than the previous year's population. Monarchs go through four or five generations a year, but only one generation migrates; the migrating generation lives nine months, by far the longest of the generations. Monarchs migrate in order to spend winters in hospitable climates; they also seek particular species of trees that provide protection from extreme temperatures, predators, and precipitation. Research suggests that their navigation is guided by how sensors in their visual system respond to the angle of polarized sunlight, and how receptors in their antennae orient them to the earth's magnetic fields. Like birds, monarchs can travel great distances by flying efficiently; they soar rather than flap their wings constantly, pace their flying in accordance with favorable wind conditions, and cluster together on trees to conserve energy. Monarchs rely on milkweed plants to survive; this is the only plant on which its caterpillars feed, and when consumed, it produces a substance that is toxic to their predators and thus critical to their survival. In response to this toxicity, other butterfly species have evolved to resemble the monarch, mimicking its appearance to successfully avoid predators [1].

One of the more compelling aspects of monarch migration is that individual butterflies migrate on their own, acting in response to environmental stimuli; still, millions arrive in

the same overwintering areas at roughly the same time. The title of my project, borrowed from Edward Lorenz's research on chaos theory in the 1960s, acknowledges this process by which individual actions catalyze complex dynamics of a larger system. Described as "sensitive dependence on initial conditions", the butterfly effect posits that any minuscule change in initial conditions can radically affect the long-term behavior of a system. For example, the flapping of a butterfly's wing produces a tiny change in atmospheric conditions, which, over time, can result in drastically transformed meteorological circumstances [2]. My musical interest, likewise, is not in creating a fixed compositional form, but a dynamic system in which the behaviors and interactions of sound objects shape the form of the piece differently each time the program is executed.

Sound As Oscillation

Sound possesses dualities of "content and form, acoustic energy and sine wave information, both substance and code, particle and pattern"; it is a mechanism for conveying meanings, and a material energy that affects and is affected by bodies and environments [3]. Scholars in the developing field of sound studies have recognized how a visualist framework has historically worked to exclude the sonic from cultural analysis. [4] A similar trend is occurring in science: Most data presentation techniques in the past have been based on visualization, but scientists increasingly explore sonification as a means of interpreting their research and recognize that acoustic patterns may communicate information more clearly than visual representations [5]. The potential for sound to relay "either and both" content and form make it a potent medium for communication in art and science [6].

Sound connects to embodied experience, life patterns, and environments by manifesting as oscillations, or repeated fluctuations in vibrational energy. Aden Evens writes: "Vibrations do not disappear, but dissipate, echoing all the while, for energy is conserved.... Even our bodies hum along with the noise of the universe" [7]. Indeed, within the human body, synchronized oscillations occur at many levels: in the cells of a particular organ, between various organs, and between ourselves and our environment (As with monarchs, our own movement patterns are synchronized, to a certain degree, by light and darkness) [8]. Oscillations are foundational to biological, physical, social, and technological systems — they are also the building blocks of electronic sound synthesis. In the musical sense, an oscillator produces a cyclical waveform. Periodic (repeating) waveforms occupy a temporal and spatial trajectory not unlike human activities and communications that also align toward "patterning and predictability" [9]. Consciousness and identity formation also emerge from cyclical patterning: For instance, we might locate oscillations within the context of Judith Butler's performative theory of gender as a "stylized repetition of acts" and in Gertrude Stein's succinct observation that "[l]oving repeating being is in a way earthly being" [10].

Methodology

SuperCollider 3 is an object-oriented programming environment for real-time audio synthesis. Its architecture is built around unit generators, which are objects (including oscillators) that process or generate sound. SuperCollider is well-suited to mapping life patterns or ecological systems because it provides a syntax for describing dynamically generated streams of events, and a means to process large numbers of objects simultaneously [11]. Object-oriented programming itself is based on a biological model: Individual "cells" communicate with each other via messages, working together to accomplish an end goal but can function independently or self-organize to solve problems when necessary [12]. Code is inevitably an articulation of human activity, which itself is "coded within social and discursive frameworks" [13]. Thus, my attempts to model an ecosystem using code exist in dialogue with the social and cultural codes that make this artistic and technological intervention possible.

I am working to isolate core elements of monarch migration (behaviors, interactions, and environmental factors) that can be deployed in combination to articulate infinite variations of a complex system. In this approach, I am indebted to the work of James McLurkin at the artificial intelligence lab at M.I.T., who develops algorithmic models for swarms of robots based on behavioral patterns of social insects. McLurkin's research focuses on how to use local interactions between proximal robots to produce large-scale behavior patterns of the entire swarm. Simple behavioral building blocks such as "cluster", "disperse", "orbit" and "follow the leader" ultimately can be combined for the self-organizing robots to address more complicated tasks [14]. Some core elements of monarch migration include energy storage (food consumption and clustering), orientation (responses to light and magnetism), and flight (wing movement offset by wind force and direction).

I propose a system of mapping in which aspects of monarch life cycles correspond to parameters of individual butterfly sound objects. In one possible system time lengths

of monarchs' three stages of metamorphosis shape the amplitude envelope; energy consumption affects frequency content; wing motion maps to amplitude modulation; direction of movement is rendered through spatialization; and the length of a complete life cycle equals one sound's duration. Predators and environmental conditions are rendered using different oscillators or noise generators than those used to describe monarchs. Techniques such as filtering (perhaps as a metaphor for wind that inhibits forward movement) and convolution might describe interactions of monarchs and environmental factors. When possible, I will map scientific data directly to numbers that generate and shape sounds in SuperCollider, or indirectly in ways that adhere to findings of the research. (I acknowledge that such a mapping system is never objective, but always an articulation of my own subjectivity in relation to programming the piece) [15].

Synthesis And Nature

I embrace synthesis not only as a mechanism for describing the "natural" but also as a means of questioning the validity of that term. In this project, scientific research is fodder for the synthesis of sound, but the "artificial" character of synthesized sound exposes notions of scientific truth and environmental preservation as social constructs [16]. In North America and Europe environmental preservation efforts have resulted in a "double ideological move [that] simultaneously commodifies nature while positing it as outside commodification" [17]. Ecotourism, including the industries in Mexico and California that accompany monarch migration, is one manifestation of this dialectic of commodification and preservation [18]. The history of much experimental music that incorporates environmental sounds similarly is characterized by the "acquisition of nature sounds" that are decontextualized from their source, mediated by layers of technology, and posited as natural [19]. Recent documentaries on migrating species not only follow this pattern but also work to prescribe universally "natural" behaviors. In *March of the Penguins*, life cycles of emperor penguins are anthropomorphized and sentimentalized; press materials go so far as to describe the film as a story of "true love" [20]. This documentary can be read on some level as re-inscribing conservative moral codes of the idealized nuclear family: monogamous parents labor to protect their unborn child, share childcare duties equally, and ultimately are marked by success through breeding or personal and social failure in its absence.

Naturalized portrayals of migration and preservation as portrayed in documentaries like *Winged Migration* and *March of the Penguins* are also questionable given that America's history and economy have indeed been built on systematic extinction of Native Americans, forced migration and enslavement of African peoples, exploited labor of Mexican and other migratory workers, a prison system that perpetuates a permanent underclass in captivity, and political disenfranchisement of transnational subjects. [21] It seems no coincidence that migration-themed documentaries with idealized portrayals of family and survival -— supposedly found already existing in nature and recreated authentically on the big screen — enjoy unprecedented popularity in America during this era in which issues such as the definition of marriage and family, as well as interests of national security and border patrol, are locked in public debate and legislative crisis.

Some of my tasks, then, in the monarch project are to locate points of rupture in the typical, heteronormative narrative of the natural. I am interested in focusing on the migrating generation of monarchs in part because it is the generation that lives longest and traverses the greatest distances. It remains in a state of reproductive diapause throughout its travel, and is the least likely monarch generation to procreate due to high mortality rates in its journey. Most monarchs — like many people — stay in one geographic location for their entire lifespan and procreate. The migrating monarchs comprise the atypical generation that does not, yet their patterns of movement are critical to perpetuating species survival [22]. By choosing to focus on this atypical generation, and by rendering their behaviors in "artificial", synthesized sound, I suggest recognizing that migration is a socially constructed, politically charged phenomenon as much as it is a naturally occurring, ecological one.

Emergence And Transduction

This project is largely informed by concepts of emergence and transduction. Emergent systems are those in which local interactions combine to create higher-level behaviors that are adaptive to environmental conditions [23]. Composer David Dunn provides important insights on making music based on emergent phenomena. In the liner notes to *Chaos and the Emergent Life of the Pond*, his audio collage of field recordings of freshwater ponds in North America and Africa, he writes: "[I]t is through listening to the pond that I am forced to grasp its wholeness. Our dependency on visual spatiotemporal metaphors eludes the dense interpenetration of living things. If one is to speak of the chaos of living systems, I prefer to hear it" [24]. Dunn's work

foregrounds the complexity of communication patterns in living systems and consistently problematizes the recordist/composer's complicity in these processes rather than claiming the recorded environment as something that can be objectively observed and preserved [25].

Transduction — generally speaking, a term for the conversion of one form of energy to another — is a useful concept for framing my project, in part, because of the obvious transductions that exist at all levels of sound recording and transmission (For example, a microphone converts physical vibrations to electrical energy; a loudspeaker carries out this process in reverse, turning oscillating current into sound waves). Like oscillations, transductive phenomena permeate biological, physical, and social realms. Adrian Mackenzie's theories of transduction provide an interesting paradigm that can be applied toward understanding expressive practices in computer music: "Transductive processes occur at the interface between technical and non-technical, human and non-human, living and non-living", a flow of engagement and interplay between divergent realities [26]. The monarch project facilitates a transduction of living patterns into abstractions of scientific research and computer programming, which are re-projected into new environments as synthesized sounds that in turn affect other living patterns.

Summary

The realm of the digital, in this project, seems ideal for exploring the realm of the wild, and vice versa: Expressions of digital and wild life exist not in opposition or parallel, but within processes of transduction. Dynamic structures of object-oriented programming offer tremendous possibility for rendering life patterns of an ecosystem; at the same time, the "unnatural" sound of digital synthesis exposes our understandings of nature as always already entwined with cultural production. If music is, as in Attali's analysis, "a herald, for change is inscribed in noise faster than it transforms society", such dynamically generated sonic models of ecosystems offer one method of making survival struggles more audible [27].

Note: "Butterfly Effects" was presented as a quad sound installation at the Mills College Chapel, Oakland, California, on March 31, 2006. Audio and video documentation are online at: http://www.safety-valve.org/bfx.html

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