Sonifying Chemical Evolution

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ABSTRACT
This presentation-demonstration discusses the creation of *FIRST LIFE*, a 75-minute mixed media performance for string quartet, live audio processing, live motion capture video, and audience participation utilizing stochastic models of chemical data provided by Martha Grover's Research Group at the School of Chemical and Biomolecular Engineering at Georgia Institute of Technology. Each section of this work is constructed from contingent outcomes drawn from biochemical research exploring possible early Earth formations of organic compounds.

Keywords
Data-driven composition, sonification, live electronics-video

1. INTRODUCTION
"A biological organism has the ability to respond to its environment and learn from its past experiences, while human designed systems are typically more rigid and thus less 'intelligent.'" —Martha Grover, *Design of an Intelligent Material,* 2011

This project attempted to create auditory models of many of the elemental and environmental conditions present in early Earth thus providing a new way to imagine the salient biochemical morphologies at play in the origins of evolution. One of the goals was to create both an artistically sensitive realization of the scientific data and to provide an educational opportunity for audience participants to engage with the fundamental principles and challenges of this multinational research project into the origins of life.

Data values drawn from self-organizing chemical compounds were assigned to the sonic properties of frequency, amplitude, duration, timbre, tempo, string instrument physical properties, and spatial location. The stochastic processes also contain Hidden Markov Models that embed a degree of probabilistic input from both the computer-generated processing and from the string quartet performers.

During performances, chemists Martha Grover from Georgia Tech and David Lynn from Emory University provided a spoken narrative about specific aspects of their research in the Center for Chemical Evolution during the five *Interludes* of the work. This created a scientific framework for each musical realization of the chemical data. The five *Interludes* were titled: *1) Miller/Urey Experiment, 2) Dynamic Kinetic Stability, 3) Emergence of a Functional Polymer, 4) Spontaneous Polymer Assembly, and 5) Biopolymers.*

There were four sections written for string quartet with live electronics. The musical structures used in writing the score for the quartet were created using the emergent patterns of four chemical elements as they form complex organic compounds in Grover's models.

This interactive composition attempts to model a biological organism's ability to respond to the conditions of its environment and to learn from its own history. Data representation types in this composition include discrete, continuous, stochastic, and interactive forms.

Audio-visual programs used in the composition of the work and discussed in this presentation are Kyma, Max, and Isadora. The live motion capture video system uses two Microsoft Kinect and is a further development of a system created in 2008 for my chamber opera, *Ophelia's Gaze.*

2. CHEMICAL BACKGROUND
The Martha Grover biochemical team at Georgia Tech designed a computer model to explore the very earliest stages of the chemical evolution of life. One of the big themes to emerge from the model is that to end up with the diverse stuff of life, information-carrying polymers must strike a balance between stability and instability. The goal of their research was to create a platform for the design of intelligent materials, which have the ability to learn from their environment. Striving to achieve this balance is similar to the manner in which the musical sections were organized in this multimodal composition.

To understand how life can begin on a habitable planet such as the Earth, it is essential to know what organic compounds were likely to have been available, and how they interacted with the planetary environment. Life can be understood as a chemical system that links a common property of organic molecules—the ability to undergo spontaneous chemical transformation—with the uncommon property of synthesizing a copy of that system. This process, unique to life, allows changes in a living molecular system to be copied, thereby permitting Darwinian-like selection and evolution to occur.

In 1953, Stanley Miller and Harold Urey, working at the University of Chicago, conducted an experiment that would change the approach of scientific investigation into the origin of life. Miller took four molecules that were believed to represent the major components of the early Earth's atmosphere and put them into a closed system. The gases they used were methane, ammonia, hydrogen, and water.

The four members of the string quartet interact during much of this work in a similar fashion to the molecules in the Miller/Urey experiments, each focused on synchronizing their movements moving between stability and instability and between different density states. Like a musical phrase, the linear association of molecules under extreme conditions may provide a new molecular idea, unexpected, one that survives within the community of molecules. The music for the string quartet is one possible realization of this idea.

3. COMPOSITION PROCEDURES
3.1 Sonification Background

The most common approach to sonifying multivariate datasets has been to map data dimensions to acoustic parameters with the goal that the information content of the data will be "revealed" through listening. This is often referred to as the "mapping problem."

In attempting to develop a sonic platform that could contain structural dimensions of the possible chemical properties of early life and rather than begin with a traditional process of data mapping, I chose to adopt the seven components or "pillars" of life as outlined by biochemist Daniel Koshland as the basis for the musical structure of the work.[1] Koshland's seven pillars are:

1. A program
2. Improvisation – which describes the possibility that a system can change its program in order to adapt to new environmental conditions.
3. Compartmentalization
4. Energy
5. Regeneration - takes into account that thermodynamic losses must be compensated for.
6. Adaptability
7. Seclusion - can perhaps be compared with "privacy" in the social world. This property of life makes it possible for many biochemical processes to take place independently in a cell without disturbing one another

These seven components formed the basis for the compositional phases of the work.

3.2 Compositional Phases

PHASE 1: Collecting data: monomers, polymers, oligomers, peptides, amino acids; RCSB PDB Protein Data Bank

PHASE 2: Visualization: PyMOL molecular visualization

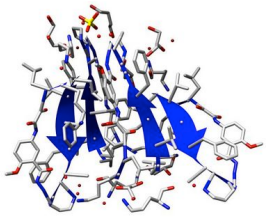

Figure 1. Peptide 3Q9H

PHASE 3: Data-driven composition: MaxMSP with IRCAM FTM objects, Open Sound Control, stochastic processes

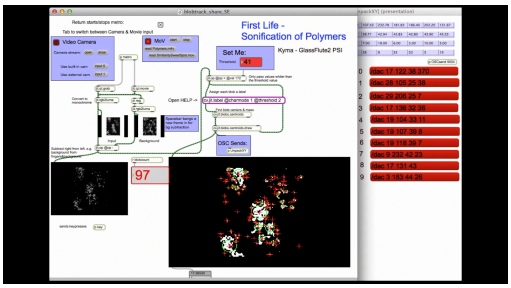

Figure 2. Sonification of monomers in Max

PHASE 4: Performer interaction / MaxMSP

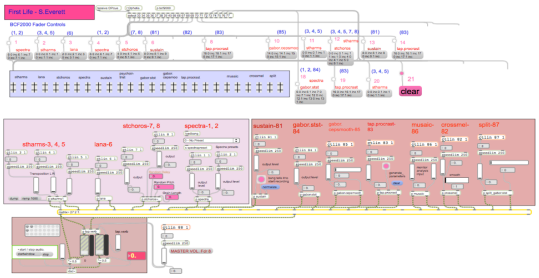

Figure 3. Max patch for live electronics

Pitch classes mapped to polymer chains

0 2 4 7 9	C D E G A
0 2 5 7 9	C D F G A
0 2 6 7 10	C D F# G Bb
1 2 5 8 9	C# D F G# A
2 3 4 7 8	D Eb E G Ab
10 1 2 3 4	B C# D Eb E
3 4 5 6 11	Eb E F F# B
6 7 8 9 10	F# G Ab A Bb

PHASE 5: Audio parameter matching: physical modeling, Kyma

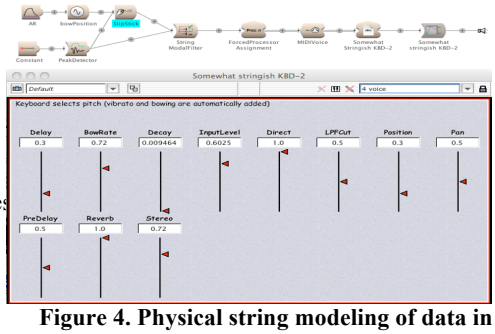

Figure 4. Physical string modeling of data in Kyma

PHASE 6: Performer-audience gesture capture and interaction:

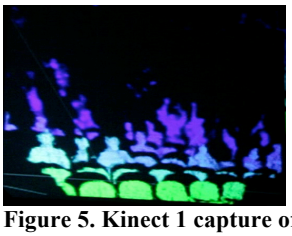

Figure 5. Kinect 1 capture of audience

Figure 6. Kinect 2 capture of string quartet

4. ACKNOWLEDGMENTS

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5. REFERENCES

1. Koshland, D. E. Jr (2002). *The Seven Pillars of Life*. Science, 295:2215-2218