

The Breath Engine: Challenging Biological and Technological Boundaries through the Use of NK Complex Adaptive Systems

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ABSTRACT

Breath Engine is an interface and performance system that draws focus to the ephemeral nature of the actions of living beings and how they intersect with the world of the artificial and computational.

The piece relies on human respiration to create and affect a generative sound synthesis system modeled on evolutionary algorithms. The respiration system is controlled by 1 - 3 participants, who wear oxygen masks that transfer the breath of the performers into electromechanical pressure sensors mounted in the project enclosure. These sensors convert the respiration levels of each performer into digital information, which is then used to affect a self-generative audio synthesis system. This generation is based on NK complex adaptive systems, which mathematician Stephen J. Lansing purports to be a potentially important factor in determining long term changes in mechanical and natural systems, such as biological evolution. This system generates iterative arrays of timbre and frequency that are perturbed by data received from the breathing sensors, causing chaotic reactions that eventually coalesce into repeating patterns.

In this way, the piece will enact an evolving visual and sonic environment that questions the boundaries between the biological and the technological.

1. CONCEPTUAL FRAMEWORK

1.1 Difference and Technology

As mobile technology incites humanity towards a way of life that is inseparable from the technological devices of our creation, it becomes ever more imperative that the philosophical and human concerns relating to questions of difference be addressed in works involving the biological and the technological. An effective way addressing these is through exploring the idea of difference.

When properly addressed, the highlighting of difference enacted in technologically-related performance practices creates contested spaces, which become sites of questioning not only technological and biological concerns, but of larger issues of difference and subjectivity. The conception of difference at play here is not one rooted in tradi-

tions of patriarchy or adversarial relationships between actors, but one that uses difference as a means of creating combinatory reactions that question the positioning of audience/performer/composer as well as the relationship between the technological and the biological. An effective method of visualizing this process is through the use of the phenomenon of diffraction as metaphor for this enacting of difference.

1.2 Diffraction as metaphor

Diffraction is the process whereby waves in motion combine and pass through each other when traveling through a given medium. Instead of reflecting and resisting other waves, they combine to enact patterns of interference that create new movement and structure based on a co-constructed enactment of difference. That is, when waves interact, they add their relative values to create a new combined value at the point of contact (see Figure 1.)

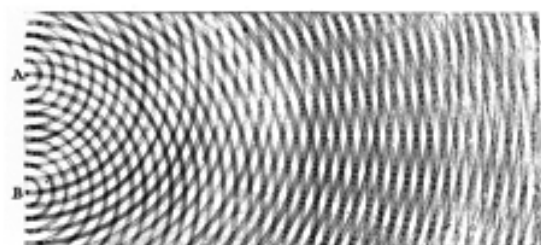


Figure 1: Illustration of diffraction created by Thomas Young in 1803. A and B represent slits in which waves are directed. When the waves interfere with one another they produce the patterns shown.

Science and Technology Studies scholar Donna Haraway outlines a valuable conceit of diffraction as a discourse for a renewed sense of understanding of difference and othering that rejects human exceptionalism. By discounting the assumption of a hierarchical system of relationships between agents in a given discourse, new methods of ideating and accepting co-constructed points of creativity can come to light. For Haraway, the idea of diffraction is important in creating a renewed understanding of how bodies both human and otherwise, interact in a co-entangled existence. This concept of diffraction is a vital lens with which to examine new possibilities of interacting and redefining our concept of interface and the agency of bodies and objects within a technological system. With this in mind, the con-

cept of diffraction will be used to conceive of new ways of defining interface and user in the performative and computation arenas. [1]

1.3 Diffraction and interface

Taken as a point of reference the concept of diffraction can produce renewed sensibilities when applied to the idea of the interface and the placement of objects and bodies within that arrangement. Difference in this context can be defined in multiple valences: human to non-human, biological to technical, audience to performer, performer to instruments, etc.

Traditional notions of traversing this difference typically position bodies and objects in mutually exclusive, almost adversarial attitudes between the human participant and the agents that surround and enable him or her. This is especially true of digital objects used in a creative or performative capacity. There is a clear demarcation of difference and hierarchical valuation present when a performer sits in front of a digital control surface and enacts his or her mastery of the technological object. The difference enacted in the traditional performer/object relationship is one of domination of the superior human subject over the inferior non-human object. This framework, although useful and convenient poses philosophical limitations in its construction of the agents involved. Applied to the understanding of the digital control surface, a model of understanding based on diffraction provides much-needed expansion of this concept.

We can see an example of this hierarchical tradition in contemporary hardware interfaces like The Akai EWI5000 wind controller. Released in 2014, this device is designed to emulate traditional woodwind operation in which a human performer uses the object involved as a conduit to deliver his or her intentionality; it specifically conforms to conventional woodwind expectations and presents as little challenge to the performer as possible. In this way the device (and others like it) position the relationship between the human and non-human actors involved in sound production to be one in which the interface objects exist only to serve the presumed interests of the human performer.

Within this discourse, the technological interface and biological agent are distinctly separate and the object clearly inferior. This perspective is made quite evident in the promotional text on the Akai website. Phrases like "(the) EWI5000 has you covered" and is "ready to perform whenever you are" make it clear that in the relationship between the object and subject, the human performer is dominant. [2] Considering this conventional conception of the digital control surface, a model of understanding based on diffraction can provide a much-needed expansion of this concept.

In a more contested interface relationship, the placement of musical production is more equally divided between the technological and other agents involved. Instead of a top-down distribution of creative power, the interactions are considered more of a collaborative effort between human and technological performers in a shared creative arena. By positioning the human-computer interaction space as one that can transcend physical boundaries, yet respect the

differentiated integrity of each embodied entity, a contested area can be created that is not firmly situated in the realm of either participant. The space is at once profoundly and almost uncannily artificial, yet decidedly human. Creating an interface that exhibits no clear prioritization of control or value to either the machine or the human agents allows a break to occur in the presumptive expectations associated with the structures of machinic dominance that can be unsettling or confusing to audiences.

Specifically, in the case of Breath Engine, the placement of bodies in a liminal space between the digital sensors and the sound-producing equipment creates a discourse in which the sound waves are sensed by and affect the human participant in ways that are often not the result of conscious decision-making, but of an embodied reactive consciousness that is out of reach of the sort of self-control assumed by human exceptionalist sensibilities. Using sensors that detect a wide range of breathing gestures, the embodied reactions of the performers are combined with specific reactive components of the computational system in ways that react to particular actions made by the performers. In this way, the arrangement of the interconnected biological and technological agents involved in the piece allow the performers bodies to be positioned as a sort of filter for data within a diffractive milieu that affords the agency of non-human objects as well as the reactive, objective potentialities of the human body.

1.4 The Body as a Diffractive Filter

By enacting the role of a filter, the bodies in this arrangement absorb the sound emanating from the speakers directly behind them and convert that energy through voluntary and involuntary reactions, which are detected by the pressure sensors and converted into digital data. This data in turn is combined with the ongoing processes of the computational system, which alter it and create changes in the audio environment, which further join with and complicate the state of being between the machinic system and the human participants. The result is an acoustical production in which the sound is directly and indirectly mapped to patterns of diffraction caused by the troubling of assumed boundaries inherent in human-computer interface relationships.

2. COMPOSITIONAL CONCERNS

2.1 Generalized Systemic Function

The performance system functions simultaneously on two levels. One is a smaller sub-system of localized time and affect in which reactions occur in a more immediate fashion over shorter durations of time. This is related to direct actions of inhalation and exhalation and the constantly changing states of difference that they co-create. The second super-system is one in which broader breathing gestures occur over the longer duration of the piece. These gestures alter the framework substantially and are directly linked to algorithmic systems that mimic the biological evolutionary functions outlined below.

2.2 Affective Localized Sub-system

The localized sub-system allows for audio to be reconfigured in a variety of ways that includes the use of synthesis and recorded audio sources. The data received from the sensors changes gain levels depending on the individual inward breath of each performer and timbral/timing effects relating to exhalation. The combined difference of the values generated by each participant alters the combinations of manipulation applied to the source audio. The values are determined by percentage of difference in sensor strength and overall averaged signal strength. Individual audio effects are allocated to positions on a spectrum of difference between the sensor levels. For example, timbral filtering is selected when the signals exhibit extreme differences in levels. The running average of the combined signal levels determines the extent to which the selected effect will be applied to the audio.

The overall aesthetic produced from moment to moment is one in which there are at times detectable one-to-one relationships between gesture and effect, but these are contained within a less obviated connection between physical effort and the produced audio, which changes over time in accordance with the complex adaptive system described below.

2.3 Affective Gestalt System

2.3.1 NK Adaptive Systems

In addition to the localized differential interactive system, longer-term changes will be actuated by the use of biological algorithms, specifically NK adaptive systems. These systems were investigated by mathematician Stuart Kauffman and others as having distinct similarities to possibly ways in which evolutionary processes can be understood to occur in nature. [3] They take their name from the amount of agents within the system represented by N , and the number of other individual points each agent is connected with denoted by K . The relative values of these numbers cause the system to exhibit three general behaviors. If the number represented by K is relatively large, the system reacts chaotically with no patterns emerging. If K is small, then activity is present for a short period of time, but quickly expires. If K is close to the number 2, then intricate patterns occur in which stability arises in specific areas, with disorder at the boundaries (see Figure 2.)

2.3.2 Compositional use NK Adaptive Systems

These systems have the property of falling into finite patterns when undisturbed, but when perturbed exhibit chaotic behavior until they fall back into a new pattern after a given time. This action of chaos followed by redefined order governs the long-term evolution of the piece over the given time period of its execution. Patterns are enacted through delay and other timing applications that outline regular temporal repetitions, e.g., a repeating delay outlining a 4/4 time signature with accents on the 3rd quarter note, etc. Over time, the collective average is monitored and when it reaches a specific level, triggers a disturbance in the NK

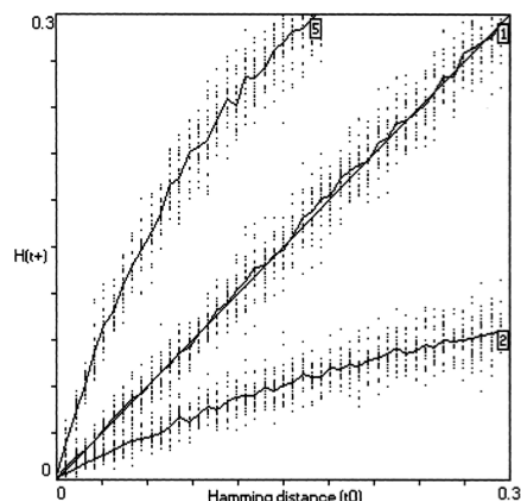


Figure 2: Derrida plot of an NK system. The x axis shows the Hamming distance of nodes of opposite value. The y axis shows the hamming distance between the two final states. Each line represents the results of K values 5, which shows completely chaotic action of the system, a K value of 1, which shows the system not exhibiting meaningful change, and K value 2 which shows the system falling into regular bins of attraction. [3]

adaptive system by injecting data into the recurrent pattern equal to the difference of the previous running average at the time of perturbation. Once disturbed, the system goes into chaos reflected in a miasma of changes and layering of differing timing effects, eventually settling into a new regular pattern of temporal affectations. The series of short-term change structures in combination with broader algorithmic long-term affectation continues for the specified duration of the piece.

3. PRECEDENTS

3.1 Technical Precedents

The use of human breath as a control mechanism for musical applications is not in itself a novel concept. There have been myriad MIDI controllers that rely on sensed exhalation pressure as a means of note onset triggers, most notably the Yamaha WX series wind controllers developed in the 1980s. The WX series controllers operate through a combination of exhalation, lip pressure, and fingering of note values in the same manner as a clarinet or saxophone.

In this sense, the WX series of controllers are referential - they are digital models of analog instruments. As breath-responsive machines, the WX series relies solely on exhalation [4]. More recently, controllers that employ both exhalation and inhalation have been developed, such as the Millioniser and the XHarp, which are modeled after the harmonica, and are thus also referential. Mobile phone technology has also made use of breath sensors. The iPhone Ocarina, developed by Ge Wang at CCRMA [5], uses the iPhone's microphone to sense air pressure from the user, and translates that information to note onset trig-

gers, which mimic the sound and operation of an ocarina. Also at CCRMA, G. Scavone developed a wind controller named "The Pipe." The Pipe employs a variety of sensors, such as force sensors and accelerometers [6], in an effort to model real acoustic instruments more accurately than controllers like the WX7. The Pipe triggers sound synthesis models developed in Cook and Scavone's Synthesis ToolKit [7].

The "Tooka" is another breath controller developed at CCRMA, but was further developed at the University of British Columbia by Sidney Fels. Like the Breath Engine, the Tooka is built for two performers. It relies on pressure sensors at the ends of the tube that allow each user to affect the output of the other. The synthesis is controlled via a Pure Data patch that interprets incoming signals, and sends that data to a Yamaha MU-100 sound generator [8].

The controllers/instruments mentioned above vary greatly, yet they share many commonalities. All of these devices rely on a one-to-one ratio of action/reaction. While some of them rely on, or afford precise manipulation of parameters, the user is always aware of and works within the notion that "this motion will necessarily create this result." In addition, all of these controllers, with the exception of the Tooka, are referential; they model acoustic instruments that already exist: The WX7 and The Pipe are fashioned after saxophones and clarinets. The Ocarina is modeled after and sounds like an ocarina. The Millioniser and XHarp are meant to function and sound like harmonicas. Another feature common to all of these instruments is the method of sound synthesis. Each controller, though by a variety of means, triggers a sound sample from an existing library or STK.

The Breath Engine deviates from the above frameworks in several ways. First, it is not referential, as it is not modeled on an existing instrument. On the contrary, the focus of its design was to specifically avoid any resemblance to an existing instrument. Second, its fabrication is wholly novel in that it contains all sensors, electronics, microcontrollers, and sound synthesis engines in the same unit. It therefore does not rely on external interfacing for output. Third, it does not necessarily rely on a one-to-one ratio of action to response. The synthesis that occurs is based on an algorithm which is influenced to varying degrees by the interaction of the performers; the NK adaptive system upon which the algorithm is modeled can cause the synthesis to react differently depending on what has occurred in the past. This also denotes a move away from the idea of simple "sound/sample triggering" in that, while audio is being activated via wavetable synthesis, the method through which it is triggered depends upon an algorithm that is contained within the instrument itself, yet is ever changing.

4. TECHNICAL FUNCTIONALITY

4.1 Overview

The Breath Engine functions through an interaction of the biological and the mechanical. It utilizes a most fundamental organic action human breath to create, synthesize, and manipulate a digitized sonic output. This section details

the method through which the participants' respiration is captured, quantized, amplified, translated, and ultimately transferred into a control mechanism for digital synthesis.

4.2 Interface Specifications

Audience members are only able to see the performers, their oxygen masks, speakers, and a black box on stage. While the performers and oxygen masks comprise the organic portion of the interface, the digital components are entirely contained within the black box: pressure sensors, operational amplifiers, power supply, PIC, Raspberry Pi computer running Pure Data, and sound card. The black box then outputs analog audio signals to a speaker array surrounding the audience (see Figure 3.) In addition to the audience speakers are two speakers (not pictured) directed at the performers, which output the audio content directly into their bodies. These provide the embodied sonic feedback essential to the proper functioning of the piece.

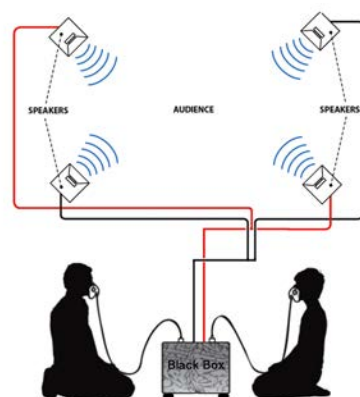


Figure 3: Illustration of the performance system and equipment in relation to the audience (illustration by the authors.)

Performers wear oxygen masks that are attached to either side of the black box. Each breathing apparatus connects to an ultra-miniature pressure sensor (MEMS 2SMPP) that utilizes piezo-resistive elements to sense the participants' inhalation and exhalation. As the output signals from the MEMS are too weak to be read via direct analog values, a series of three LM324 operational amplifiers is used to boost the initial input values of each sensor. The op-amps, at each consecutive stage, are filtered with variable resistors leading from the output of the MEMS to the positive input of the op-amp. This allows for tuning of the input signal to assure for equally tempered values from each sensor (see Figure 4.)

The amplified signals are then received by the analog input pins of an Atmega 328 PIC. The Atmega 328 reads, in succession, each analog value and stores that value in a variable. Each variable that the Atmega 328 chip receives is then sent over serial port to the Raspberry Pi. The Raspberry Pi runs the Pure Data program, which receives analog values from the Atmega 328 via the [comport] object, which is a Pure Data external object that stabilizes serial communication between the host controller and con-

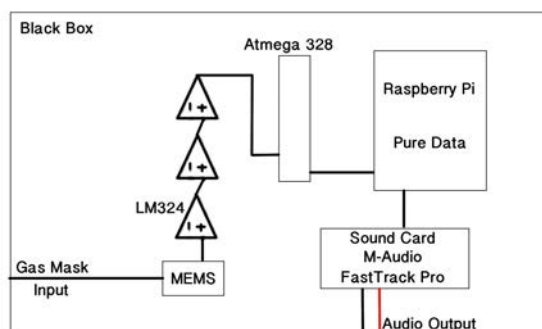


Figure 4: Diagram of the computational and amplification system inside the Black Box (illustration by the authors.)

nected devices. The incoming values from [comport] are then parsed and used as starting points for the NK Complex Adaptive Systems (CASs) that provide the primary synthesis algorithm that establishes and reshapes the sonic environment according to longer-term changes in the environmental data (see Figure 5.)

5. CONCLUSIONS

This piece is intended to be just one voice in a continuing conversation about difference and technology. By using these multiple systems in combination with philosophical theoretical perspectives, a methodology of creative production can be enacted that takes into account the technical and biological systems involved, without privileging either. In enacting the piece it is our hope that it will not only be aesthetically moving, but also compel audiences to consider the consequences of technological production and the instantiation of discreet boundaries between objects, humans and the entangled interdependencies that construct culture and meaning.

Acknowledgments

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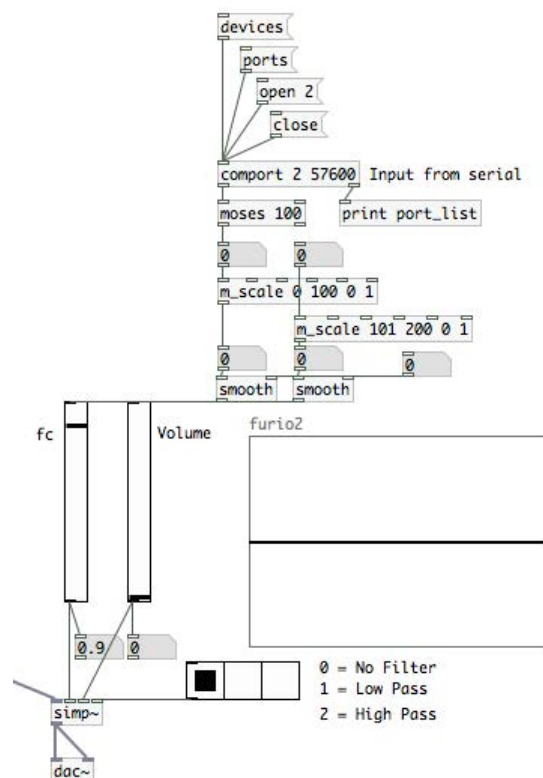


Figure 5: Image of Pure Data program that parses the incoming data from the sensors to be used to affect the sound output (illustration by the authors.)

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