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For

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QUALIFICATION QUESTION #1

Exploiting the Pathology in/of Media in Art

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QUESTION

Natacha Diels

Through the lens of three works — William Basinski's *Disintegration Loops*, Anthony Vine's *Tape Piece*, and your own *descent* series — discuss the ways in which the deliberate misuse or exploitation of weaknesses of a system have been harnessed as aesthetic material towards predetermined or experimental artistic ends. Consider cultural expectations and implications in this context, relationships to existing genres in music or art, and potential commonalities or differences shared across the pieces.

1. Introduction

In Zachary Bushnell's unpublished short story *Divers*, the protagonist becomes obsessed with Greg Louganis' infamous accident during the qualification rounds of the 1988 Olypmics in Seoul.[1] The protagonist watches the video of the incident obsessively, finding Louganis' body during the dive to be deeply moving and more honest than any of the contrived moves one might find in a conventional diving competition. The way the body goes limp; the way the limbs float freely, unencumbered; the efforlessness which seems to emanate from a body which has momentarily lost all reference to the external world and instead reflects back onto a single point of pain on itself, certainty of its existence pressed hard into its material being.

There is certainly something very beautiful and intoxicating about failure. The trouble with this entire phenomenon, though, is what to call it in the first place when applying it to artwork. It seems natural to want to call it "failure" but that seems to

[1]Bushnell, *Divers*, unpublished manuscript

exclude a great deal of existing work but does not “fail” in any way. Or sometimes, a failure is not a failure at all but rather illuminates other aesthetic experiences hidden under our own expectations. In another example, sometime in the early 1980’s Robert Rowe of MIT rigged a rather expensive Bösendorfer piano with solenoids for a machine realization of a work for piano by the composer Iannis Xenakis. What Rowe did not account for was the amount of heat the solenoids would produce when driven fast enough to create the piece. The heat ignited the spruce and the piano burned to the ground.[2] Did the Xenakis piece fail? Yes, the piece was not realized because the piano burned down. Was the performance a failure? Not at all; in fact, it was probably one hundred times more interesting. It is clear that using this word “failure” to describe either accidental and intentional aesthetic activities of this kind is problematic.

The word that best describes this set of practices is *pathology*, in the sense that what is being exploited for aesthetic ends might be construed as a weakness, a failure, or a *disease*, to borrow the lexicon of medicine. Surely in a studio, one wishes to limit all external interferences, all external sound sources or influences on the sound recording and playback processes. One wishes to limit the unintentional coloration the studio provides as a mechanism and only allow that coloring that is desired and can be controlled. In the archive, one wishes to preserve an artifact and prevent its degredation to ensure accesibility to future researchers. In memory, one wants to believe that memories are accurate and revisitation functions like one might view a book, whereby the contents of the book are not altered upon viewing. This is a natural set of values to have and are indeed values that are imparted on us by our culture. In fact, they are often *good*: recordings need to be accurate, artifacts must be preserved for future study, constantly questioning the veracity of our memories would lead us to certain madness. What happens, though, when one inverts this set of values, bringing forth that which is otherwise hidden, ignored, or intentioially obfuscated?

[2]Relayed during a conversation with Miller Puckette

2. Three Pieces, briefly

Three pieces were chosen for this project: William Basinki's 2001 ambient work *The Disintegration Loops*, Anthony Vine's 2019 sound sculpture *Tape Music*, and my own 2012 (ongoing) series entitled *descent*. Each of these works share a common aesthetic essence in which the utilization of a systemtic weakness is exploited for artistic gain. Interestingly, all the works are concerned with mechanisms that record information: tapes, in the case of the Baskinski and Vine, or memory, in the case of my own work. It is though perhaps less a requirement and more an acknowedment of the fact that our technological media, from the very beginning, is built around having *memory*. Even the most simple digital filters have a memory of a single sample and the entire idea of *feedback* as defined in Norbert Weiner's *Cybernetics* and as we understand it today is predicated on machinic memory. It is then perhaps appropriate that each of the three works engage on some direction level with the idea of memory, whether that be magnetic or psychical.

Indeed, many works that engage in this mode of operation work on some level with the nature of memory. The vinyl works of Christian Marclay[3] and Czech artist Milan Knížák or Yasunao Tone's seminal 1997 work *Solo for Wounded CD*, for instance, engage with memory in various forms: as changing ridges in a groove or as binary data on a plastic disc. The German band Oval fits here, too, though in a slightly different way than those just mentioned: the material of the CD skips are taken as material from which another strucuture, in their case a track on an album, is produced. The arhythmic brutality of Tone's work is substituted for a sleek and polished product which, nonetheless, is born of the same desire: that of using the machine itself to create material via latent weaknesses. The process is different, too: Tone disables the CD players' anti-skip mechanism which results in unfiltered error, the player rendering exactly the data it recieves from the damaged CD. Oval, on the other hand, wrote on CD's with felt markers and did not disable the anti-skip mechanism; in fact, it is the skips themselves which give the work the character it possesses.

This does not mean to say, however, that the pathology of media is possible

[3] *Record Without a Cover* and other broken record words

only through those information recording mechanisms but it is an interesting theme throughout many works that exist in this mode of operation. In the following section, the works are discussed in more detail. The section serves a descriptive purpose; that is, it simply functions to describe the pieces as they exist and makes little to no attempt to analyze the work musically, socially, or conceptually. The idea is to frame the pieces in such a way that viewing them through the lens of pathology is clear. It would certainly behoove the reader to listen to those works that have been published; namely, *The Disintegration Loops* and *descent*.

2.1. *William Basinki's* Disintegration Loops *(2001)*

Among the more famous of the ambient works from the early 2000's are William Basinski's *Disintegration Loops* where the decaying ferrite on magnetic tape loops creates the formal progression of the work. In the words of Basinki himself: "I went to make a cup of coffee in the kitchen, came back and was listening, and I started noticing something was changing. All of a sudden, I looked and I could see dust in the tape path. I thought, 'Oh my God, it's happening.'"[4] It is clear that the work was *discovered* as almost a kind of aural ready-made, a process waiting to be set in motion and captured. The sounds themselves were originally produced by Basinki in the early 1980's and consisted of various sources: found sounds, radio, orchestral segments, etc. Basinki released four separate albums of the loops totalling nearly five hours of material. The tracks range from twelve minutes to over an hour and are sometimes fragments of other loops that appear on other tracks. The simplicity of the work makes the process of decay much more palpable.

Unrelated to the project at hand but nonetheless a crucial happenstance that helped frame the work was the fact that Baskinski claimed to have finished the piece on the morning of 9/11 in his Brooklyn apartment. The gentle decay of the tape stands in stark contrast to the brutal collapse of the World Trade Center but both are nonetheless locked in a parallel process of destruction, decay, and breakdown.[5] *The Disinte-*

[4] Gotrich, "Divinity From Dust: The Healing Power Of 'The Disintegration Loops' "

[5] It seems to me, though, that it would have been incredibly poetic to save a tape or two for an unrecorded "live" performance where those in attendance would hear the decaying in real-time and once the tape had played itself out, it was never to be heard again.

gration Loops were subsequently dedicated to the victims of the attacks.

2.2. *Anthony Vine's* Tape Music *(2019)*

Anthony Vine's recent work *Tape Music* uses inexpensive tape decks to play back sine tones as a way of "[embracing] the generative capacities of these devices" and to "bring the idiosyncracies of each machine — motor speed, speaker distortion, and enclosure resonance — into relief..."[6] The 45-minute work (the duration of a single side of casstte tape) exists in three versions: *Unisons*, *Octaves*, and *Motors*. By superimposing the sonic output of the devices, one is able to hear the minutaue of the imperfections of the devices.

Unisons and *Octaves*, as the names imply, use sine tones that are tuned to either unison at 300Hz or to octaves of 60Hz (120Hz, 240Hz, 480Hz, 960Hz, 1920Hz). The choice of 60Hz in *Octaves* is significant: it is the frequency at which AC power comes through outlets in the United States. It serves as a way of fitting the working into an already present background, a way of embedding the work into the ever-present industrial structure on which it depends. Both of these rely on the inconsistency of the players during playback (as well as the inconsistency of recording, as the tapes were recorded on the same devices) to create the relief necessary for the work to function and to create its temporal and conceptual structure. Naturally, the effect is far more pronounced in *Unisons* for the simple reason that small deviations in frequency are more immediately palpable when those two pitches are closer together in terms of their numerical frequency value. It is also the case that Vine "tunes" each player to create an ideal sonic projection that combines not only the recorded sine wave (and its own idiosyncracies created during its recording) but also the added harmonics of the amplification circuit and the cheaply made speaker contained in the apparatus. It should be stressed that the presentation of the work does not come accross as clinical in its bringing-to-relief of the inconsistencies, as the effects of the amplifier, speaker, space, and motion and position of listeners are all critical components of the work. It is stark, to be sure, but possesses more a quality of Robert Rauchenberg's *White Paintings* rather than the sterility of scientific experiment.

[6]Email correspondence with the author, May 15, 2019

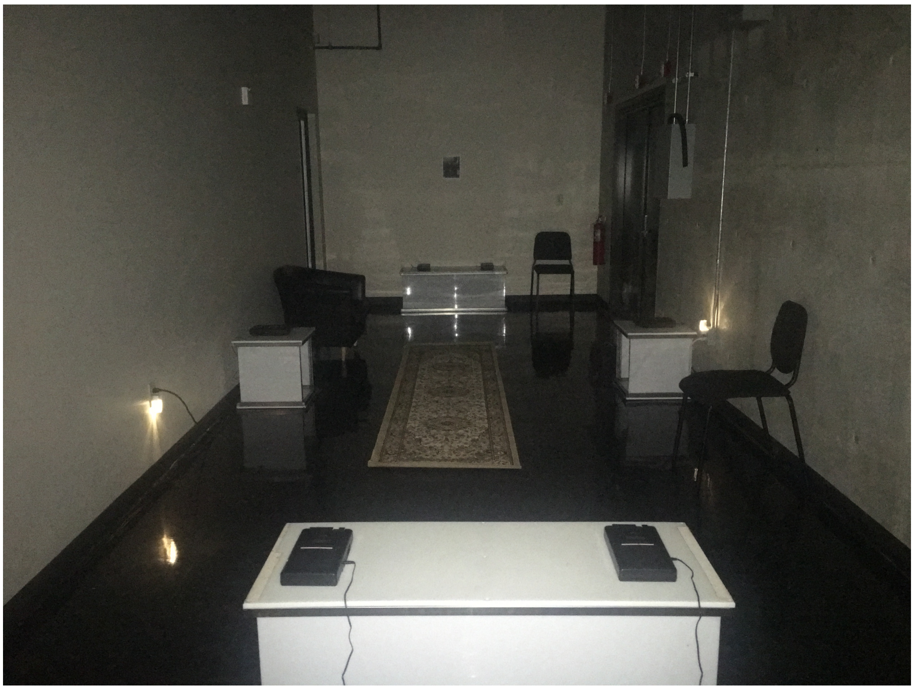

Figure 1. Anthony Vine's *Tape Music* as presented on March 3, 2019. Note the six players on the white tables: two in the foreground, two in the background, and one along each side of the space.

Motors, on the other hand, does not relieve the players of their assumed equality in the same way as do *Unisons* or *Octaves* and instead acknowledges their inequalities directly. The sine waves recorded onto the tape *reflect* the pitch of the speed of the motor, transposed many octaves higher. In this way the players point back to themselves, as if looking in a mirror in the only domain in which they viably can, and highlight or shine a light onto the differences between themselves and the other players instead of bringing the differences out via a comparative listening process. It nonetheless utilizes a similar principle: that of the machinic inconsistencies as a formal device. What's more, though, is that due to the combination of recording and playback on a single tape player, there is no guarentee that the tone being projected several octaves higher is indeed *actually* reflective of what the motor is doing *at this moment*. That is, the mirror into which the device gazes is curved, warped, and give it — and the listener — a false impression of itself.

2.3. *Jacob Sundstrom's* descent *series (2012 - ongoing)*

The *descent* series takes the maleability of memory as its starting point and in contrast to the other works presented here, utilizes this "brokeness" as a conceptual framework for a compositional series for solo piano. The idea is that each subsequent iteration of the piece strays further and further from the original "memory", distorting its identity as the one-who-remembers attempts to recall the passage in whole but in recall, inevitably changes it.[7] Although I did not know it when I first began the project, this is indeed not far from the truth.[8]

Thus far, three versions have been produced: #1, #2, and #7.[9] #1 is the original memory, unadulterated, the piano solo presented as itself without any extraneous intervention. It is the memory as it was imprinted on the psyche. #2 begins to show the first signs of distortion: a simple "selective reverb" is added which unsettle the harmonies of the piano as if the memory begins to question itself. Temporal and harmonic reflections of the original are created and begin to create friction with the acoustic piano. By #7, however, the memory has broken down completely: there is no more acoustic piano in performance and the temporal identity of the original has vanished, displacing both the pacing and reinventing the harmony. The entire memory has stretched — from 5' to over 21' — as the one-who-remembers searches for the truth that remains as it bounds down corridors into ever shifting passages.

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[7] One thought I had with regard to the same body of work was to create it *without* electronics and make the experience of recall far more concrete. Essentially, I planned to memorize the original work. Then, say six months later, attempt to play it from memory and memorize the new version. Then six months later, attempt to play the remembered version and memorize the new iteration. And so on, ad nauseum. Of course this could still be accomplished but as of now, I've begun to feel increasingly disenchanged with music as a whole... I digress.

[8] Schiller et al., *Preventing the return of fear in humans using reconsolidation update mechanisms.*

[9] A peculiar feature of the *descent* series is the fact that the three versions produced thus far were produced out of numerical order. That is, #7 was produced before #2, and #1 has never been performed for an audience. This is perhaps due more to my own pathological natures than any conceptual pathology used in the creation of the works. However, with respect to the conceptual nature of the process, one need not wait for decay to occur but one can impart decay onto an existing object.

3. Pathology as an Aesthetic Material

> "I have always said: Penetrate the machine, explode it from the inside, dismantle the system to appropriate it."
>
> - Paul Virilio in *The Accident of Art*[10]

Taking the word at face value, pathology is the study of the essential nature of disease; specifically, the *cause* of disease and the functional and structural changes associated with disease in the animal. It is additionally defined as the "deviation from" a norm of a material that can be either living or nonliving.[11] Taken literally, it is the "study of" (-logia) "experience" or "suffering" (pathos).[12] There was much wrestling with the terminology to describe this phenomenon: other authors have used "failure",[13] "destruction",[14] or "glitch".[15] Failure, though, has far too many negative connotations and often times there is a clear *lack* of failure in these works. Destruction is likewise too strong and does not cover works that are not destroyed. Glitch, likewise, has its own set of problems.[16]

Paul Virilio might argue, though, that these are all rather an "accident" and are the negations of functioning technology. This would certainly be consistent with a pathological outlook as long as one took note of the causes and function the accident occured in. His "Museum of Accidents" is a codification and an explicit acknowedment of the inverse of functioning technology as serving a function in culture.

The following sections outline various pathologies that one might associate with the aforementioned works. It is, of course, not exhaustive as far as pathologies in art is concerned. Much thought went into whether or not to break apart the pathology of magnetic tape and its recording/playback device. If the medical field is any indicator, it makes sense to break these categories apart since the *nature* of the two are

[10] Virilo, *The Accident of Art*, 74

[11] Merriam-Webster entry for "pathology"

[12] It is quite wonderful that the Ancient Greeks used the same word to describe both suffering and experience; depending on one's inclination, they might be equal. That is, one cannot gain experience without suffering or hardship of some kind. Note that hardship can also be a sign of growth.

[13] See Cascone

[14] See Menkman

[15] See Manon and Temkin; Betancourt

[16] See the discussion on Glitch Art below.

fundamentally distinct though they are certainly interrelated and, more importantly, interdependent. Nonetheless, the function of the tape itself is to *store and record* information, while the function of the player is to *impart or retrieve* information from the world to the tape or visa versa. Thus, their underlying pathologies will be related but nevertheless distinct.

3.1. *Pathologies of Magnetic Tape*

What, then, is a pathology that effects the ontology of the casstte tape itself? To make the question more appropriate, what is an aesthetically useful pathology of a cassette tape? Certainly a crack in the casing will not necessarily cause any harm in the recording or reproduction of the information which is contained on the tape. It might endanger the information on the tape but it does not impact the information itself. Given that the nature of the cassette is to *store and record information*, any aesthetically useful pathology will engage with the information storage and transmission capabilities of the object. Damage to the reels or the magnetic tape itself seem like obvious and natural places to start.

3.1.1. Basinski

The pathology with which *The Disintegration Loops* were created came about from literal old age. The tape has experienced a *mechanical senescence*[17] wherein its functional qualities deteriorated as a function of age (as distinct from deterioration from *usage*). To use a medical analogy, the tape became diseased as a result of old age and when asked to perform a function it could in its youth, it perished. It is not dissimilar to an elderly animal acquiring a disease in their late stages in life, almost a sort of mechanical Alzheimer's disease where the subject is left not in a state of confusion and dimentia, but rendered rather mute and catatonic.

While a precise diagnosis of the specific mechanism at play in the Basinksi is impossible without examining the tapes themselves, a knowledge of the construction of tapes in general can shed light onto what likley caused the deterioration. The magnetic ox-

[17]Indeed, even the field of engineering has recognized the aging of materials. See Valliappan and Chee, "Aging degradation of mechanical structures"

ide particles that actually encode the information are bound to the physical tape with a pigment binder (i.e. the glue that keeps the magnetic oxide particles together and on the tape itself). A process known as hydrolysis — wherein a chemical breakdown occurs due to the presence of water — has been noted to occur in many tapes from the 1970's and 1980's as a result of storage of the media in a humid environment. The moisture in the atmosphere is absorbed by the pigment binder, resulting in a condition called pigment binder hydrolysis, wherein the polymer loses its binding property.[18] As the tape that has experienced hydrolysis is passed through a player, the action of bending, pulling, and passing over by the felt and read heads caused the magnetic oxide particles to fall off. On each subsequent pass in *The Disintegration Loops*, less magnetic material was avaialble for the induction of a magnetic field and thus, "holes" grew in the sound. This also explains the fact that upon listening to *The Disintegration Loops*, high frequency information is sometimes lost before the entire sound goes silent. The cause of "tape hiss" is due to the granular nature of the magnetic oxide particles on the tape, often as small as 0.5 micrometers in size.[19] When these particles fall off, their granular nature is disrupted and thus, high frequency information is lost.

3.1.2. Vine

For Vine, mechanical senescence is not part of *Tape Music*'s current identity. On inexpensive cassette tapes, the magnetic oxide is likley to be more inferior that that of more quality tapes (iron oxide as opposed to, say, chromium dioxide). An inferior magnetic oxide reduces the capacity of the tape's ability to store accurate information in the form of a reduced signal-to-noise ratio and a smaller dynamic range. Even if one were able to transmit a perfect waveform (sine wave, in the case of *Tape Music*), the inferiority of the cassette itself ensures a less-than-perfect record of the signal. This is in turn amplified by the inferior playback and recording mechanism on the deck itself, described in the following section.

A critical difference between Vine and Basinski, apart from mechanical senescence,

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[18] UNESCO paper on magnetic storage. Boston, *Memory of the World: safeguarding the documentary heritage, a guide to standards, recommended practices and reference literature related to the preservation of documents of all kinds*

[19] Nave, "Tape Head Action"

though, is that the errors during recording (and playback, for that matter) are not acreted as they are in the Basinski. This concept, though, is one that Vine has expressed interesting in pursuing in future iterations of *Tape Music*.

3.2. *Pathologies of Tape Players*

Vine's work, although it certainly engages with the pathology of the cassette tape, is more related to the pathology of the tape players themselves. This occurs in the stages of both preparation (recording) and presentation (playback) and is due in large part to the inferior quality of the devices used in the piece. *Unisons* and *Octaves* specifically embrance the inconsistency of the motor speed in the tape players while *Motors* illuminates the motors as sound producing entities in and of themselves.

3.2.0.1. Recording and Playback. Inconsistencies that are captured during recording are subsequently amplified in playback during *Tape Music*. However, without a systematic study of the players, one can only make conjectures as to the actual errors they produce. Nonetheless, one can postulate that inferior construction materials — such as resistors, capacitors, and the materials of electronic circuits — and design contribute in the largest way to this inconsistency. In a way, *Tape Music* is a mechanical parallel to the process found in the *descent* series. In *Tape Music*, errors in recording are amplified by the inconsistent playback mechanism, as well as the amplification apparatus. This is similar to the process of recollection and could be made more direct if the tape could somehow record back onto itself each time it played through.

3.2.0.2. The Amplification Apparatus. The distortion caused by the speaker and circuitry plays a crucial role in the perception of both *Unisons* and *Octaves*. By raising the amplitude of the output, the amplification apparatus (circuitry and speaker) is overdriven and cause the waveform to distort. This distortion thereby creates high frequency harmonics not present in the original but nonetheless directly realted to the original waveform. When these distorted waveforms are then overlaid, they create various acoustic and psychoacoustic phenomena such as interference patterns or sum and difference tones. These phenomena thus index various aspects of the tape player as machine: the speaker distortion, circuitry inconsistency, and motor speed inconsistency. The last item, that of motor speed inconsistency and the presence at all, is what is indexed in particular in *Motors*. The amplification apparatus thus serves to highlight that which it is designed to cover; namely, the sound of the motors.

Mechanical senescence might yet become a part of *Tape Music* as there has been a noticable deterioration of the playback mechanism on the devices.[20] This might be more due to the frequency of usage of the devices as opposed to their old age specifically, however. In Vine's own words: "Sometimes, these changes and aberrations in the sound are quite extreme and drift away from established intention of the piece. Something very tightly wound begins to unravel overtime into unforeseen forms; something new is born out of their breakdown... Now that I am aware of this phenomena, I am eager to create something that addresses it directly: perhaps, a continuously running and sounding tape piece that gradually falls apart due to the mechanical demands of continual playback. "[21]

3.3. *Pathology of Memory as a conceptual framework*

Using the pathology of memory as a concept is, of course, specifically related to the *descent* series where memory is taken as unstable. One must ask, though, if the reconstructed version of this memory — of any memory — is somehow closer to the truth than a precise recall, as it contains embedded in itself our desires, prejudices, insecurities, and dreams. A further critical and somewhat unrelated aspect of this work has to do with the desire to acurately remember certain events. Since the mere act of remembering necessarily changes the nature of the memory that is being remembered, one is faced with a critical decision: how often should one remember? That is, given a particularly vivid and strong memory of a situation which brought rapture and ecstasy, say, one of a situation that occurs few times in life but which one wishes to revisit, how often does one responsibly remember without somehow distorting crucial

[20] Email correspondence with the author, May 15, 2019
[21] Email correspondence with the author, May 15, 2019

details by remembering too frequently and also avoid forgetting crucial details by not remembering often enough? Again, though, perhaps the distortion that occurs ends up being more honest than the original memory in the first place.[22]

As noted previously, this indeed has some basis in the real process of memory recollection as discovered by neuroscientist Daniela Schiller.[23] What Schiller and her colleagues have found is that the emotional experience of a memory can be altered well after the event has been stored in long-term memory and that memory recall consists of "reconsolidation" of an event. That is, memory consolidation occurs when the brain imparts an event into long-term memory and consists of synthesizing protiens; reconsolidation, the act of remembering, also consists of protien synthesis and this process can be interuppted to form new information that is associated with the memory. In the words of Schiller: "My conclusion is that memory is what you are now. Not in pictures, not in recordings. Your memory is who you are now."[24] This is indeed aligned with the idea that *descent* seeks to explore: namely, that the reconstructions are somehow more honest, more true, in a way, than an accurate recollection. What does this then say about our human experience?

Likewise, another of the questions *descent* sets out to explore is addressed by Schiller: "The safest memories are those you never remember."[25] They may be safe but if they are going unremembered, are they valuable? Moreover, is there a risk of forgetting it altogether or, upon recall, altering more than if one were to recall it regularly? One could also take the statement at face value and ask if something goes unremembered, can it fairly be called a memory in the first place? To be more pointed, is an unrecallable memory a memory at all? The answers to these questions are left to the researchers in that domain.

What is curious, though, is that this may not be a pathology in the sense it has been used thus far in the text. If Schiller and her colleagues are correct then this reconstruction is a *normal* function of memory and recollection, and therefore not an

[22]This, of course, is a somewhat old work and while I sometimes fantasize about completing other versions, new works come to mind which, frankly, I find more interesting. It is interesting to take note of these tendencies near the start of my creative practice where I was attracted to concepts that I had not yet found words for but have continues to become clear and mature as I continue making work.

[23]Schiller et al. 2010

[24]Schiller as quoted in Hall, "How We Might Take the Trauma Out of Bad Memories."

[25]Schiller as quoted in Hall, "How We Might Take the Trauma Out of Bad Memories."

abberation, not a deviation from a norm. Is this then not a conceptual appropriation of pathology of memory and if it is not, does it then not fall under an exploitation of pathology in the arts? While it is true that it would not be *strictly* pathological, it seems that the fact that it is counter to our cultural and intuitive sense of memory is enough for it to be labeled as such.

4. Heidegger's Hammer

In *Being and Time*, Martin Heidegger speaks of the various ways we might interact with objects of the world and the modes of encounter we experience phenomenologically. Among his most oft cited examples with regard to *equipment* is that of the hammer: the hammer as present-at-hand, the hammer as ready-to-hand, and, interestingly, the hammer as un-ready-to-hand. For Heidegger, an object, specifically *a tool*, is ready-to-hand when it is phenomenologically transparent to the user. In the case of the hammer being used *skillfully* by, say, a carpenter, the hammer acts like an extension of the body of the carpenter and the carpenter, in the act of hammering, does not have awareness of himself as a subject over a world of objects. The experience is only that of the task being performed and the objects employed in the fulfillment of said task are transparent. When the carpenter breaks the hammer rendering it *unuseful*, the hammer becomes what Heidegger calls *un-ready-to-hand*; "When [the objects] unusability is thus discovered, equipment becomes conspicuous. This *conspicuousness* presents the ready-to-hand equipment as in a certain un-readiness-to-hand."[26] (Emphasis original)

What of this *un-readiness-to-hand*? The phenomenological category of un-readiness-to-hand is presented as a spectrum of various states which "disturb" an assignment and that this mode can take several forms: a broken tool, a tool which is missing, or a tool (object) that is neither missing nor broken but that "stands in the way" of completing an assignment. In the first instance, that of a broken tool, the object presents the itself as *conspicuous*; that is, its readiness-to-hand is stripped away revealing its un-readiness-to-hand. The way Heidegger uses "conspicuous" gives the sensation of an immediate change of mode, a quick or violent withdrawl of usefulness. This could be

[26]Heidegger, *Being and Time*, pg. 73

considered the basic form of un-ready-to-hand that Heidegger is conerned with. In the case of a tool which is missing, the un-readiness-to-hand of the equipment moves that which remains as ready-to-hand into a mode that Heidegger calls *obtrusiveness*; that is, "The more urgently we need what is missing... the more obtrusive does that which is ready-to-hand become."[27] With an object that "stands in the way", the "*obstinancy* of that which we must concern ourselves in the first instance before we do anything else."[28] That is, the *task* which must be performed to resume work becomes stubborn and obsinate.[29] It is interesting that each of the variations Heidegger points out seem to point to slightly different things in the experience of the world: the broken object itself (conspicuousness), the unbroken tools (obtrusiveness), or the task which is newly presented and must be completeled before one can resume (obstinancy).

4.1. ***Discussion***

The attitude of pathology in artmaking could be construed as an aesthetic investigation of the phenomenological mode of the un-ready-to-hand object (an object under a pathology). It is an acknowleding that the un-ready-to-hand may be revealing of something that is not quite so apparent when the same object is taken to be present-at-hand in a "useful" form. It is taking what might be considered un-ready-to-hand in a certain context and showing that it still possesses a readiness-to-hand when held in aesthetic contemplation. Indeed, the un-readiness-to-hand of the object is potentially revealing of certain underlying natures of the object that remain hidden even when the object is present-at-hand (i.e. the object is held apart from its context in a disinterested mode). This notion is echoed in Ed Halter's *The Matter of Electronics* when he says, "The very moments that indicate the specificity of the medium occur when that medium starts to break down, to suffer and reveal imperfections. The technology becomes visible through its failures."[30]

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[27]Heidegger, *BT*, pg. 73

[28]Heidegger, *BT*, pg. 74

[29]It is interesting to note what the three variations of un-readiness-to-hand Heidegger presents us with point to. The *conspicuous* variation points back to the object that has just revealed itself as un-ready-to-hand. In the case of the missing object, the *obtrusiveness* is with regard to the other objects in the immediate environment. With the final case of an object that "stands in the way", the *obstinancy* point to the newly discovered obstacle that must be overcome in order to resume work.

[30]Halter, *The Matter of Electronics*, pg. 72

Both works by Vine and Baskinski do this rather explicity with the latter being perhaps most interesting in this regard. What we witness in *The Disintegration Loops* is the transformation of the object from being in the mode of ready-to-hand as a musical tool to the mode of being un-ready-to-hand as a tape that has lost its ontological function of the capture and reproduction of sound. It is this process which is made into an aesthetic journey and presetned for contemplation.

Vine, on the other hand, utilizes techniques and equipment that would be considered inferior and would thus interfere with the aesthetic experience when placed in the value strucutre of traditional "high-art" music. He instead inverts the value system and uses the "weaknessess" of the equipment to index their inconsistencies and foreground latent properties of the objects as processess and objects worthy of aesthetic contemplation. Curiously, but not surprisingly, the physical materials that constitute *Tape Music* — the tapes and their players — are also beginning to break down mechanically, likley due to their inferior nature. What appears to be happening parallels that of what *The Disintegration Loops*, only on a much longer timescale that could only be wholly appreciated by those listeners who have heard the work from its original instantiaition. This is at once fascinating and problematic for Vine, as, for *Unisons*, "tones must fall within the critical band to create vivid beating between the fundamentals and most importantly, forge a singular and unified sonorous field."[31] What this means for the future identity of the work — that is, the work as played on *those* tapes and *those* players — remains to be seen.

My own work differes from both Basinksi and Vine in that it does not take a physical, un-ready-to-hand object as its aesthetic driver but rather abstracts the process of transformation of memories from ready-to-hand to un-ready-to-hand. When does a memory become un-ready-to-hand? That is, when does it become so distorted, so changed that it is rendered unuseful if one were, say, on the stand at trial and under oath? This is, of course, assuming something such as a memory could be contemplated in the phenomenological modes Heidegger applies to objects. It is interesting to consider that if a memory, altered from recall, does possess a certain character of truth that *cannot* be found in a "photographic" recollection, can the memory recalled, then,

[31] Email correspondence with the author, May 19, 2019

ever be unuseful? It seems that in this case, the nature of the modified memory speaks more about who one is rather than what the memory is of.

The acreted breakdown that the *Tape Music* is beginning to experience and what makes *The Disintegration Loops* possible, though, is reavealed only through the passage of time and through the wear and tear of the physical devices. This process is much like erosion whereby various hidden layers are exposed slowly, often with soft edges. There is, however, a process more akin to excavation with heavy equipment and dynamite: that of forcing media to interact with processes that it was not designed for, to force it through a hole into which it does not fit. In this way the idiosyncracies of the medium are brought into relief by force, by pushing the medium to its breaking point where it inadvertantly reveals natures otherwise hidden. In one of the earliest works of video glitch art, Jamie Fenton's *Digital TV Dinner* from 1978 (Fig. 2), a Bally Astrocade game console is physically punched while attempting to write to its ROM memory. This causes the cartidge to physically move and ultimately eject from the machine and this physical disturbence interrupts the memory writing function of the console, causing it to write nonsense (to some) to its output. Here the contrasat between approaches is striking: in *The Disintegration Loops*, the media perishes of "natural causes" (i.e. old age, in this case) while in *Digital TV Dinner* the media is executed. Both objects are rendered unuseful (un-ready-to-hand) but the difference is the means and speed at which that phenomenological mode is acheived.

A related phenomenon is that of manufacturing defects or design flaws. They can be viewed, certainly, as un-ready-to-hand and when held in aesthetic contemplation, the disfigured object can reveal properties of itself that are overlooked or taken for granted when the object is phenomenologically transparent as ready-to-hand. Specifically, there was a time I flew on a flight and recieived a package of airline peanuts that was empty. I was, of course, mildly irritated but also thought it wonderful that such a product had made it through the factory without being filled, past quality control (assuming there is QA for airline peanut packages), through the stewardess and all the way to my seat, 30,000 feet in the air where, for a brief moment, Hephaestus smiled down upon me in an otherwise dry, long, and cold flight. Another example: at west end of the Price Center at the University of California, San Diego, there is an automatic door

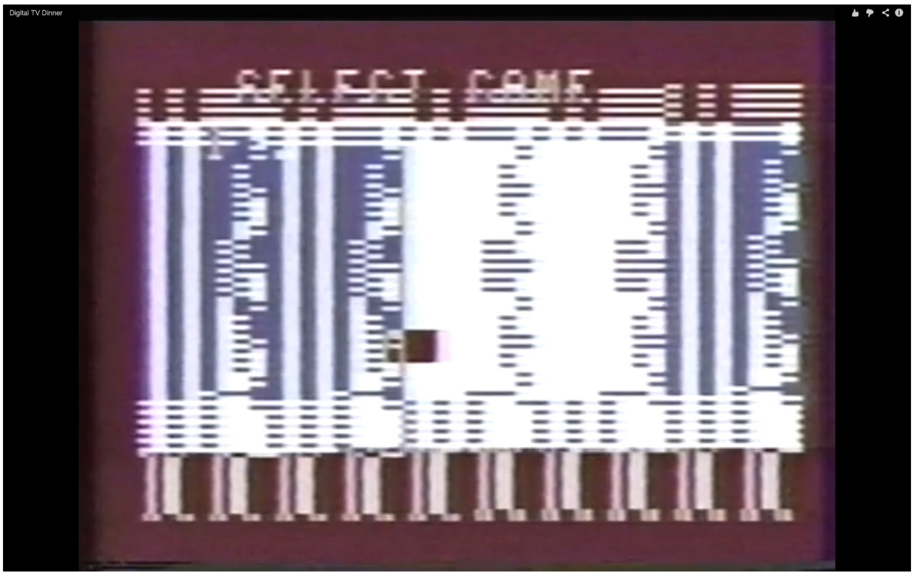

Figure 2. Screenshot from Jamie Fenton's *Digital TV Dinner* (1978)

opener for wheelchair-bound individuals that opens into a foyer that is only escapable by stairs. (Fig. 3) How wonderful! How unuseful!

5. Related Practices: Glitch Art

The reader may notice a conspicuous lack of the term "glitch" throughout the text (except when refering to Jamie Fenton's *Digital TV Dinner*); this was done deliberately and carefully. Given the ubiquity with which that type of art and label abounds, it feels rather natural to classify works such as *Digital TV Dinner, Solo for Wounded CD*, some of the works by Oval, or any number of distjunct, fragmented, and "broken" work as "glitch". Indeed, many authors have.[32] However, labeling these and other similar artwork "glitch" is a conceptual and linguistic misnomer, more likley the result of intellectual sloth than a careful consideration of the semantics of the word.

What is a glitch, then? The definition of glitch is almost as elusive as that of cybernetics; a definition is likley more reflective of the interests and knowledge of the person providing the definition than it is of illuminating what a glitch is in the first place. Etymologically, it derives from the Yiddish term "glitshn" which means to slip, slide, or glide, while the first usage of the term associated with technical failure was by

[32] See Sangild, Betancourt, and Manon and Temkin

Figure 3. Handicapp door opener that opens into a stair-protected foyer.

the astronaut John Glenn to refer to electrical problems on spacecraft.[33] Many of the artists and theorists who have written on glitch give a definition that circles around various ideas of "failure" or "destruction," (Menkman) whether that failure is "minor" (Sangild), "major" (Manon and Temkin), "[simulates] risk" (Manon and Temkin),[34] and "technical failire" (Betancourt) to name a few. Interestingly, Rosa Menkman's *Glitch Studies Manifesto* does not use the term failure at all but uses instead "destruction," and rather attempts to discuss what glitch does and means semiotically as opposed to what it is. However, the document is so riddled with contradictions, banalities disguised as weighty proclamations, and questionable intellectual stances that it is hardly worthwhile to address it here despite its unbiquity in the practice.[35]

5.1. *Discussion*

This label is often applied hapharzardly and superficially to works possessing the *character* or *appearance* of machinic malfunction (digital, analog, or otherwise) without

[33] Sangild, *Bad Music*, "Glitch - The Beauty of Malfunction"

[34] How a failure can be both major and a mere simulation that entails no risk is beyond me. It seems that if it is a "simulation" of failure it cannot be an *actual* failure at all.

[35] That is, unless, one were to interpret the *Manifesto* as a glitch of manifestos — that is, a failure — then it may then be particularly valid. But if her other writing and work is any indication, one must assume that she is indeed serious in which case the *Manifesto* ought to be forgotten in the heap of dusty and empty artistic manifestos where it belongs.

necessarily *being* a malfunction. Indeed, much of what is termed glitch is simply the result of feeding a computer or circuit bad information;[36] for instance, feeding a sound program the data of an image. The program interprets the data as the user wishes and has no qualms when asked to play back droning or screeching noise. This process does not make the result a "glitch". Even more blasphemous are the "glitch" programming languages or "glitch" filters for consumer camera devices,[37] products designed to produce the appearance of malfunction with none of the systemic risk associated with actual malfunction.[38] These sorts of products completely ignore the ontology of a glitch as a potentially dangerous malfunction and instead appropriate the least interesting and most superficial aspects of what malfunction might produce. It appears that the term "glitch art" has been captured and held prisoner by dilettantes of the Internet, and is now suffering from Stockholm Syndrome where it has sold its soul to cheap effects and shallow edge.

Indeed, this idea of danger and risk is embedded deep in the discussion of glitch. In Manon and Temkin's *Notes on Glitch*, there are three entire points on whether or not a glitch is actually a dangerous thing. Manon and Temkin make the case that a glitch is almost excluslvey a digital phenomenon and that as such, it is only "simulated risk" since the undo operation is baked into the digital. This is true if one works in a program that allows an undo operation, saves the file somewhere else beforehand, or only tampers with files that are not vital to continued operation. It certainly can be risky if one is working with something that does not allow an undo, on a single file of which there is only one copy, or manipulating files integral to the operation of the machine. The risk is simulated only insofar as one wants to limit the risk and one could easily play "glitch games" with something much higher stakes. Seeing it this way also completely precludes circuit bending as a form of glitch (which is also questionable).

Regardless, a full discussion of glitch is beyond the scope of this text; suffice it to say that the term is so bloated and disparately defined as to be virtually meaningless both as a practice and a category. Additionally, the definitions given end up either excluding many practices that might be called "glitch" or betray the notion of risk

[36]In computer programming, the term for this stage in debigging is called *fuzz testing*.
[37]See Polarr
[38]It is the aesthetic equivalent of gym climbing; that is, climbing with none of the interesting parts.

baked into the term. That seems a project better reserved for those who care about categorizing works; i.e. art theorists and art historians. Artists engaged in a creative practice would do well to completely ignore the discussion about how their work might be categorized.

5.1.1. Glitch as a Subpractice of Pathology in Art

The entire notion of glitch could be ostensibly subsumed into the larger idea of exploiting a pathology as aethetic material. It is engaging with particular pathologies and often what might be called *induced* pathologies; my manually disturbing the stucuture of a digital file one induces a change that most would charactarize as a glitch but the specific mechanism is unimportant to call it an investigation of a pathology. Thinking of it this way does not betray the etymology or ontology of what a glitch might be and in fact avoids the most useless of the semantic discussions surrounding the term. It rather gets to the heart of the concern: that of bringing to the surface underlying, hidden, or obfuscated properties and of aesethetically reframing what might otherwise be considered a flaw.

Epilogue: It Doesn't Have to Be Fun to Be Fun — The Limit Experience

Something else these practices have in common — and a personal interest of mine — is the idea of the limit-experience found in Michel Focault's readings of Neitszche, Bataille, and Blanchot. This inclination, for me at least, extends well beyond the way I am interested in treating materials or even my creative practice in general. In much the same way that Focault describes a limit experience — as looking beyond the phenomenological experience of reflecting "on the everyday in its transitory form" (Foucault, *The Order of Things*, pg. 241) and instead trying to reach a point as close as possible to what might be described as "unlivable" — I find the experiences to be most interesting, dangerous, and rewarding.

What does it mean for something inanimate to have a limit experience? This was touched on in §4.1 when the contrast between the process of creation in *The Disintegration Loops* and *Digital TV Dinner* was discussed. The process of the latter —

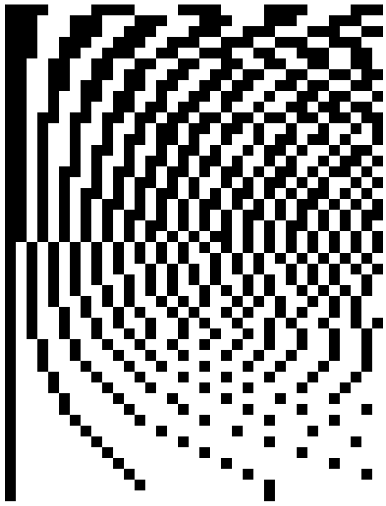

Figure 4. Exposure timing sheet for Tony Conrad's *The Flicker*

execution as opposed to a slow gentle death — comes closer in spirit to the limit experience as Focault speaks about it. It is almost as if the material, the media itself is pushed into its own type of limit experience whereby it reveals itself in new ways by experiencing not what is "unlivable" but by being put on the edge of becoming something it is not, by being brought close to death. This is perhaps most easily seen in circuit bent electronics, especially those who respond well to voltage dropouts. When one wires up a potentiometer between the power supply of the batteries and the rest of the device, one essentially starves the device of its life force and, being choked, the device does strange things it otherwise would not do.

A work that comes to mind is Tony Conrad's 1966 experimental film *The Flicker*. Composed exclusivley of black and white frames, except for the opening credits and accompanying medical warning, the film alternates the two in different ratios starting slow and ending up quite rapid to produce stroboscopic effects. At the piece's apex, the black and white frames alternate every single change, resulting in a switch at the frame rate which is often between 24 and 30 frames per second. Physiologically, different parts of the eye have different response rates which likley accounts for some of the properties of the stroboscopic effect produced by the film.[39]

One can approach this in a couple of ways. The first is to move the eyes and look about when the image becomes intense. Doing so ensures that one's head never throbs,

[39] Richard H. Maslan, *Vision: Two Speeds in the Retina*, 2017

the eyes do not fatigue, and the mind remains relatively sharp. At the other end of the spectrum is when one tries as much as possible to *not* blink, to *not* look away, and to stay focused on the sensation without following excuses to avert the gaze. Doing this results in wild visuals that tax the optic system and make the it seem as if the image has somehow bled out into the rest of the space, the mind recoiling in horror as it becomes enveloped in the sensation. The eyes struggle to adjust and beckon one to look away, begging for respite from the onslaught of the extremes of stimulation, light and dark. What is this but a limit experience for the optics?[40]

[40] A curious thing about it is despite the duration of the stimulation, the threshold in which the stimulation becomes a background is never crossed: the mind is not able to dull the stimulation regardless of the duration.

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QUALIFICATION QUESTION #2

The Use and Abuse of Flocking Algorithms for Music

Jacob Sundstrom

QUESTION

Miller Puckette

Of the various ways flocking algorithms could be used to control the production of musical sound, which are the ones that you think are most promising musically? Are there examples of electronic music that use flocking effectively? What sorts of behavior are flocking algorithms capable of and how would you translate them into sound?

1. Introduction

One need only watch a murmuration of starlings undulate, wave, and stretch to experience the remarkable collective behavior found in almost all social organisms (starlings are particularly remarkable). Fish, bison, and even human beings exhibit similar behaviors in large groups whereby changes in direction, orientation, or speed are observed to occur without a central control or leader. In fact, shoals of herring up to seventeen miles long have been noted to occur in the wild; it is clear that there is no single leader directing the motion of the fish.[1]

Algorithms that simulate the collective behavior of biological systems have seen signifcant use in computer art since Craig Reynolds published his seminal 1987 paper *Flocks, Herds, and Schools: A Distributed Behaviroal Model.* In his paper, Reynolds outlined three "rules" with which one can model flock-like behavior in a graphical computer simulation, often called the *boids* algorithm for a bird-like or "bird-oid" entity. The algorithm found usage in early computer animation in feature films such as a colony of bats in Tim Burton's *Batman Returns* (1992) and a confusion of wildebeest

[1] Reynolds, *Flocks, Herds, and Schools*, pg. 1

in Disney's 1994 animated film *The Lion King*.[2,3]

The phenomenon underlying this is called *emergence*: "emergence refers to how collective properties arise from the properties of parts, how behavior at a larger scale arises from the detailed structure, behavior and relationships at a finer scale."[4] That is, emergence occurs when properties observable in a collective are not present at the individual level. Part of its beauty (at least as far as programming is concerned) lies in the fact that one need not explicity design into the implementation these sort of properties; they "emerge" as a function of local interactions. The fact of prescribing a set of simple rules to a collection of entities that exhibit very complex behavior is immensley attractive, perhaps even dangerously seductive, a siren song lulling unsuspecting researchers toward the rocky coast of musical mediocrity.

The question naturally arises: how might one apply concept this to sound? The obvious answer found itself in the practice of sound spatialization.[5] By using a speaker array of sufficient resolution and an appropriate panning paradigm, sound sources can be made to appear to fly about the space by assigning a sound to each agent in a flock. In fact, my own interest in flock-like algorithms was born out of experiments in the spatialization of sound using a flock-like paradigm. However, these simulations are merely mathematical models and the output need not be space in the conventional sense; that is, the attributes of the agents in a flock can be used however one sees fit and need not align with notions of up, down, left, or right. Despite this obvious possibility, there have been relatively few forays into the usage of flock-like collections for non-spatial sound processing, limited to a handful of documented cases.[6] Interestingly, instaces that have been well-documented have been used as either real-time score generation (Cádiz) or improvisation (Blackwell, Hembree, O'Brien (who's work is derivative of Blackwell's)) while no documented instances have been used for "predetermined" work in the form of a fixed score.

This text reviews two well-documented instances of flock-like behavior in non-spatial

[2] Allers and Minkoff (*Lion King*); Burton, Tim (*Batman Returns*); Tiemann

[3] Variations of this algorithm would also certainly produce phenomena similar to that of an *unkindness of ravens*, a *hover of trout*, or a *clowder of cats*. For additional and wonderful "terms of venery" the reader is directed towards James Lipton's *An Exaltation of Larks*.

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[6] Blackwell, Huepe et al., Davis, O'Brien, Hembree

domains: those of Tim Blackwell and Christián Huepe, Marco Colasso, and Rodrigo Cádiz as published in *Controls and Art*.

2. Two Flock-like Algorithms

Below are preseted two common flocking models, both of which have been experimented with in music and sound. The first — Craig Reynolds' boids — can be considered the godfather of flocking algorithms, is extraordinarily flexible, and produces quite convincing motion when visualized. The second — the Vicsek model — is a more simple model that nonetheless produces convincing motion, as well.

It should be noted that in each of the models below, periodic boundary conditions are assumed. That is, the system is bounded or wraps such that the virtual space is not infinite. If it is left unbounded, the flocks will forever move in a single direction (Reynolds) or will disintegrate into non-interacting individuals (Vicsek). Unfortunelty, the sound examples from Huepe et al. which use the Vicsek model are unpublished and one must rely on spectrograms to imagine the output.

2.1. *Reynolds' Boids Algorithm*

The flocking algorithm authored by Craig Reynolds in *Flocks, Herds, and Schools: A Distributed Behaviroal Model* is THE classic flocking algorithm and has been used innumerable times in commercial products to create convincing flock-like collective motion without needing to specify the precalculated paths of each individual agent. Reynolds distilled biological flock-like behavior into three rules:

(1) Cohesion: stay close to neighbors
(2) Separation: avoid colliding with neighbors
(3) Alignment: attempt to match the direction and speed of nieghbors

The flock itself is composed of agents that move about the flock-space and posses two primary attributes: a position and a velocity. Both position and velocity are vectors of size N where N is the number of Euclidian dimensions in the flock-space; i.e. a 2D plane is a 2-element vector, a 3D space is a 3-element vector. Note that although it is natural to think of and implement a flock in a two- or three-dimensional space, the number of dimensions is mathematically arbitrary but must be greater than zero.

2.1.1. Implementation

Implementation of this algorithm essentially involves creating a discretization of Newton's laws, plus the three "flocking" rules. At a time step t, each rule is calculated for each agent, A_i, and the result of each rule is summed to get a new velocity, $v_i(t)$, for each agent. The newly calculated velocity is then added to the previous velocity, $v_i(t - \Delta t)$. That velocity, $v_i(t) = v_t + v(t - \Delta t)$, is then added to the previous position to get a new position for the next time step. Each of the rules are described below with pseudocode at the end of the text.

2.1.1.1. Rule 1: Cohesion. The principle of this rule is that the members of the flock must attempt to stay near their neighbors and thus do not wander astray. In other words, each agent possesses an *attractive* force within a given radius of their position. A critical aspect of this rule is that a given agent takes its center to be the center of its *neighbors* and not the whole flock[7] When the percieved center of an agent is only the average position of its neighbors as opposed to the entire flock, the flock is allowed to split if an obstacle is encountered which makes for more realistic simulations. The individual agent does not care that a large portion of the flock has gone a different direction if it can remain close to its neighbors.

Implementing this rule involves creating a new velocity vector that is equal to the average position of those agents that are within a given radius; i.e. the neighbors that are within the agents "field of perception". That is, the sum of the positions of the neighbors, A_p, are averaged, P_{avg}, which is then added to the velocity. It has been noted that birds in real flocks take note of the positions of their five or six nearest neighbors in their field of vision *regardless of their distance.*[8] It seems, though, that this would be useful only in the case of a very complex field in which various attractors and repulsors that may split the flock into many smaller parts or a large field in which

[7]Reynolds refers to taking the center of the whole flock as a *central force* model which gives slightly different behavior.

[8]M. Ballerini et. al., *Interaction ruling animal collective behavior depends on topological rather than metric distance: Evidence from a field study.* 2008.

agents might become "lost" would this rule be useful.

See Reynolds, Rule 1 in the Pseudocode section.

2.1.1.2. Rule 2: Separation. Separation, or collision avoidance, rule two seeks to ensure that each agent does not collide with neighbors; that is, each agent possesses a *repulsive* force within a certain radius of their position. With this rule, another constant is often, a *minimum distance*, which is the distance the agents wish to have between themselves, or the threshold at which their mutual repulsion falls to 0.

In calculating separation, the algorithm only takes note of the position of those agents which are within the minimum distance, d_{min} from the agent which is being calculated, A_i. If a neighboring agent, A_j, is found to be within this threshold, the position of A_i is subtracted from the position of the neighbor, A_j, such that the difference vector, p_{diff}, is equal to $A_i(p) - A_j(p)$. This value can be scaled with a function such that the agents are repulsed "harder" the closer they become but this is not neccessary for the algorithm to function.

See Reynolds, Rule 2 in the Pseudocode section.

2.1.1.3. Rule 3: Alignment. Alignment, or velocity matching can be also thought of as providing cohesion as in the first rule, but in the domain of velocity. That is, while the first rule attempts to ensure that all agents do not drift too far *spatially*, alignment attempts to ensure all agents do not drift too far in terms of *velocity* — their speed and direction. Reynolds describes velocity matching as "a predictive version of collision avoidance: if the boid does a good job of matching velocity with its neighbors, it is unlikely that it will collide with any of them any time soon."[9]

This is accomplished for each agent, A_i, by taking the average of the velocities of its neighbors, V_{avg}, and adding them to the velocity of A_i. This is often multiplied by a constant such that the agent is only influenced by its neighbors and not beholden to them. Importantly, setting this constant to zero nullifies this rule causing the agents in the flock to become uncorrelated in terms of the velocity leading to something that resembles flies: a mass moving about, uncoordinated but, because of rule one, tending

[9] Reynolds, *FH&S*, pg. 28

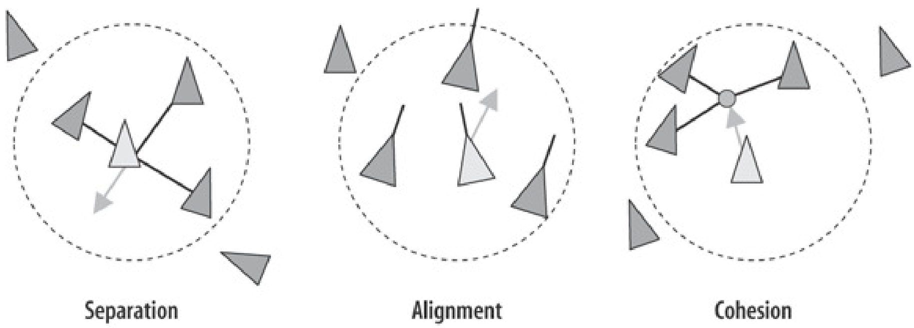

Figure 1. A graphic visualization of the rules in the Reynolds model.

to want to remain together. This is a central concern of Tim Blackwell's *Swarm Music*, discussed at length below.

See Reynolds, Rule 3 in the Pseudocode section.

2.1.2. Attractors and Repulsors

The behavior of the agents in the flock can be made more complex by the addition of attractors (targets) and repulsors (obstacles) to the field in which they move. This behavior is similar to that of the first and second rules (centering (attraction) and separation (repulsion)). The primary difference, however, is that the precise nature of the targets and obstacles can be defined by a user[10] and given a position and a "weight"; i.e. a force of attraction or repulsion.

The targets or attractors possess a field in which an agent is drawn to it which is scaled by a constant, g, the weight. It is useful to think of a target much like a mate which gives off pheremones or a mass in space in which the gravity falls off as distance increases. The nature of this field is arbitrary though my own research suggests that a rule of g/r, where r is the distance from the agent to the target, produces good results. The common inverse square rule, or g/r^2, by which both gravity and perception of amplitude are governed, gives less than satisfactory results since an agent is not attracted to the target until it is already fairly close or the force is so high that an agent is unable to later escape. This is of course desired in some cases but the motion created when a flock is pulled in to a target from a distance through a field can be quite mesmerizing.

[10]Or from the agents' perspective, "God".

Repulsors or obstacles function almost exactly inversely as targets; however, the nature of the fields often must be different to ensure interesting behavior. In fact, my own implementations use g/r^2 as the field of repulsion so that the agents are repulsed only when they are quite close; otherwise if one uses g/r, agents often go out of their way to avoid even approaching the obstacle.

2.2. *The Vicsek Model*

The Vicsek model of flocking was developed by Tomás Vicsek and his colleagues, published in 1995, and used by Huepe, Colasso, and Cádiz in their chapter *Generating Music from Flocking Dynamics* from *Controls and Art.*[11] In the basic form of this model, each agent, A_i, possesses a position, p_i and a direction expressed as an angle, θ_i. Note that the speed of the agents in the Vicsek model, V, is constant since the velocity attribute found in the Reynolds is simplified to an angle.

In contrast to Reynolds' simulation, the agents are coupled only through alignment of their angles that steer them toward the average direction of neighbors within a given radius, plus noise. Note that this is quite similar to rule three of Reynolds' algorithm except the Vicsek adds a degree of uncertainty by default. With low enough noise, all agents' motion converges and they move in a similar direction. When the noise increases, they become decorrelated and disorganized. The noise itself can be characterized in one of two ways: extrinisc or intrinsic. With extrinsic noise, the noise values come from "errors" the agents make about their environment (i.e. the velocity of their neighbors; uncertainty) while intrinisc noise could be considered "free will" of the partciles where they "decide" to move differently than the rule tells them to. What occurs depending on where one places the noise is the speed at which the transition between coherence and non-coherence occurs for a collection of a given size.[12] The primary benefit of this model is its simplicity while still enabling convincing simulations.

[11] Vicsek et al.; Huepe et al.

[12] Hernandez-Lopez, Rogelio A., "Modeling Animal Behaviour - Vicsek Model"

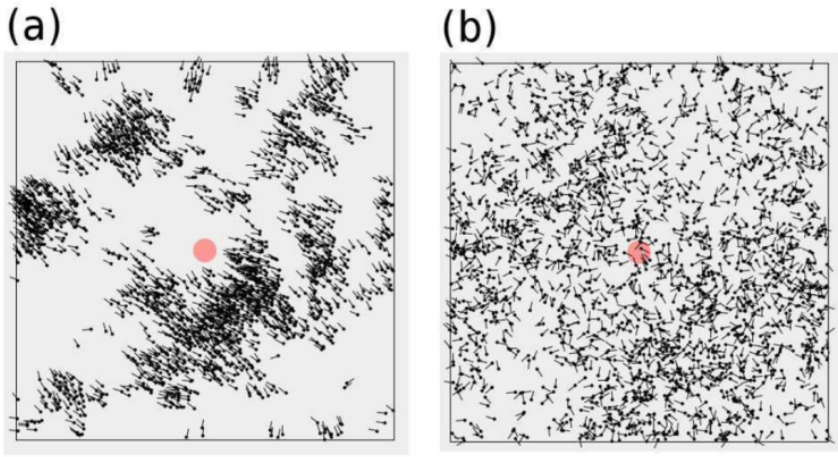

Figure 2. A graphic visualization of the Vicsek model showing low and high noise situations.

2.2.1. Implementation

Implementation is likewise more simple than the Reynolds. At each time step, t, the calculation of a new angle, $\theta_i(t+\Delta t)$, is performed by averging the angles of the agents within a raduis, r, and adding noise, η. A new position, $p_i(t+\Delta t)$, is calculated by adding the old position to a unit vector pointing in the direction of $\theta_i(t)$, scaled by the fixed speed, V, such that the new position is equal to $p_i(t) + (V \times u(\theta_i(t)))$ where the function $u(.)$ produces a unit vector of the same angle as its argument.

Interesting properties of the Vicsek model are the creation of spatiallialy correlated groups moving in similar directions despite the absence of an attractor rule such as the one found in Reynolds. These groups tend to be larger the lower the noise level and continually break into smaller groups as the noise increases; i.e. more "individuality" is perceptible. The addition of noise is also the reason a collection would eventually break apart in an unbounded space.

See Vicsek in the Pseudocode section.

3. Mapping

Mapping is concerned with the process of extraxting information from the simulation and using that information to effect some sonic quality.[13] The information is often

[13]I debated here whether to qualify the effect as *intuitive* whereby mapping some piece of information onto some or other parameter makes *intuitive* sense. I refrained, however, due to the fact that it is often the case

that of the collective attributes of single agents such as position and velocity, but can also include "meta" properties such as density, distribution, cohesiveness and the like. It seems that the most ground is lost with new innovations when it comes to mapping the information they are able to uniquely output. All too often, a new interface does not capitalize on its ability to work outside of the traditional signifiers of music. (i.e. information that could ostensibly be captured by notation) For example, touch technology has been used in as an interface to produce pitch. However, the layout of the interface is that of a traditional piano thereby imposing the cultural domination of twelve-tone equal temperament on an interface that does not imply any temperament or even any mode of interaction whatsoever. It seems a truly wasted opportunity.[14] Using flock simulations in a convincing manner in sound, then, hinges on an effective and robust mapping strategy.

3.0.1. Direct Mapping

In a situation of direct mapping, the state of each agent is directly mapped to various sonic dimensions. That is, given a single agent, its position, velocity, and/or heading are directly translated to a musical dimension such as pitch, amplitude, spatial position, grain size, transposition, etc. It is perhaps the most obvious means of mapping information contained within the simulation and fairly easy to implement. Indeed, this is what Blackwell does exclusively and a strategy that is tested by Huepe et al. Blackwell uses a space of up to six dimensions and maps onto each axis various musical parameters such as pitch, interval, amplitude, event (phrase) duration, inter-pitch duration (whether the event has the quality of a chord or phrase), and the sequence that the pitches appear.[15]

Huepe et al. took a slightly different approach. In their study as opposed to mapping a single dimension, say the x axis, onto a frequency range, they instead used the x coordinate as the frequency of a tone and the y coordinate as the frequency of the modulator in amplitude modulation (AM) of that tone. In their study, however, they opted to not use the AM component and keep the amplitude constant in order to

that non-intuitive mapping is more interesting but far more elusive to create convincingly.

[14] See the The Roli Seaboard Rise.

[15] Blackwell, *SoM*, pg. 132

simplify analysis. In the study, Huepe et al. concede that while the sounds mimic the individual dynamics of each agent, they "do not convey the strong feeling of cohesiveness, strucutre, and emergence that is apparent to the eye when viewing the simulations."[16,17] The authors claim that collective strucutres, such as clusters that naturally form in the Vicsek model, are not well-reflected in the sonic output when mapped directly. This ought to be no surprise as the direct mapping technique does not take into account the relationships between and among the agents in the simulation. However, since the x axis was mapped to the frequency *and* if two clusters are separated along the y axis with the x coordinates are relatively similar, it follows that one would not be able to distinguish between clusters. Thus, careful consideration of the dimensions of mapping must be made in order for the collective behavior to be heard.

Moreover, the authors note that "the periodicity of the box [enclosure in which the flock is simulated] implies that when the frequency associated to a given particle reaches its edge, it must instantaneously jump to its opposite extreme value."[18] This criticism seems misplaced, as it is an implementation issue as opposed to an issue that is directly attributable to a direct mapping strategy. For instance, this problem could be mitigated by treating the bounds of the box as *hard*, causing the agents to bounce off. Likewise, the edges of a dimension could be made identical with the maximum (or minimum) value at $x = 0$ or $y = 0$ (the center of the square) such that when a particle wraps to the opposite edge, it is as if it simply changed direction.

It could perhaps be made to enable the hearing of the clusters by mapping the states of the agent to more meaningful musical dimensions or by increasing the range in which the mapping occurs. That is, amplitude ought to be used and while it certainly simplified the analysis, it likley did a disservice to a true analysis of the possibilities of direct mapping. Likewise, the range of mapping and the speed at which that range is traversed certainly plays a pivitol role in the audibility of the collective structures found in flocks.

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[16] Huepe et al. *CA, MFD*, pg. 162
[17] Therein lies the potential issue with *all* flocking methods
[18] Huepe et al., *CA, MFD*, pg 164

3.0.2. Oscillator Coupling

Huepe et al. propose another mapping method which they call *oscillator coupling.* The aim of this method is to "capture the coherence of the trajectories of different agents over time,"[19] and is performed by a frequency consensus among neighboring agents. To be more explicit, each agent is given a random "preferred" frequency and a range of interaction which is larger than that of the Vicsek model (since interactions with that range are guaranteed by the algorithm). As agents move about the space, their frequency outputs are a weighted average of its own frequency and those of its neighbors such that agents moving in clusters will converge on similar frequencies while agents moving independently will stick to their preferred frequency. These attributes are tempered by two additional values: a rate of frequency convergence on the average, and the weight of its own preferred frequency.

3.0.2.1. Amplitude-Cluster Coupling. Amplitude is also coupled with neighbors. The amplitude of the output is such that there is defined a minimum and a maxiumum. When the agent is in isolation, the amplitude is equal to the minimum. As the agent acquires neighbors, the amplitude eventually saturates at the maxiumum. This could be extended to account for clusters in different dimensions: that is, in a two dimensional projection of a 7-dimensional space, one can find (or induce) clustering in dimensions 1 and 2, while being is absent from dimensions 5 and 6. This could help mitigate the problem of hearing clustered agents even in the direct approach and could be mapped to various dimensions since in an N-dimensional flock, clustering can occur and be lacking in multple dimensions simultaneously.

This method produces sounds that refect the emergence of polarization order but make specific spatial dynamics harder to hear (according to the authors). Again, these statements are hard to evaluate in the absense of concrete audio examples.

[19]Huepe et al. *CA, MFD*, pg. 164

3.0.3. A Model of Friction or Collision

In the physical friction method proposed by Huepe et al., an artificial "friction-like" process is created which produces sounds when agents make contact (i.e. venture into the range of influence). The authors take as their phystical paradigm the model in which frequency is dependent on the speed each moving component in an apparatus (such as an engine), as opposed to the fundamental oscillation of the objects (as in a bowed instrument). Thus, the frequency of each agent in Huepe's implementation is "proportional to its relative speed with respect to the moving average position of its neighbors".[20] This means that agents which move in a cluster (i.e. along with others in the same direction) will have a low relative velocity within their range of interaction, while a flock in a high state of disorder (high noise in the Vicsek model), agents do not move in groups and thus the relative velocities between agents can be quite high.

This creates interesting results which produce various outlying events due to the nature of the implementation and do not statically converge on a specific frequency range. That is, if there are two clusters in the field, they will each tend to converge around a low relative velocity and become similar in frequency-space. When they pass near one another, however, those agents on the outer edges of the clusters will come into each others range of interaction and their relative speeds will be much higher than the relative speed of those in their own cluster. Thus, these interactions will trigger outlying events which "sparkle" in different parts of the spectrum if the output is mapped to frequency.

What is not clear in the implementation by Huepe et al. is how the sounds are triggered or what sort of envelope they possess, since the spectrogram suggests that, unlikle the previous two methods which use a continuously sounding tone, the friction method uses discrete instances of sound. However, this seems to have little impact on the audibility of the process at hand.

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[20] Huepe et al. *CA, MFD*, pg. 167

3.1. *Discussion*

In the examples of Huepe et al., the mapping of frequency is merely a convenience and it is perhaps better to think of the output as an *attribute* of an agent or collection of agents. That attribute could thus be mapped onto any dimension such as pitch, amplitude, or duration. Moreover, there is no particular reason one could not use multiple strategies simultaneously, nor the same strategy with different parameterizations or in different dimensions entirely. That is, one could utilize a strategy in some dimensions but not others; i.e. if one wanted an "active" flock to ensure activity in some domains (say, onset triggers) but wanted less change in other domains (say, pitch), one could ascribe more degrees of freedom in the calculation in the latter while restricting it in the former. By using the model of friction along one dimension to create many onsets (since it relies on proximity to create its effect), one could use the same strategy in three dimensions to create the changes in pitch. This would allow differentiated densities with the same underlying flock behavior.

The latter two methods of coupling and friction could be implemented in the Reynolds model. There lies a choice, then, in whether or not to couple the range of interaction necessary for the mapping strategies to the minimum space parameter the Reynolds model uses. If, for instance, the minimum space between agents is modulated in real-time and the range were not coupled to it, the minimum space could be made larger than the range and the agents would only interact when their momentum or attraction to a target exceeded the repulsive force between them. This would effectively limit the interactions in the range required by the strategy and thereby dampen the sonically perceptible motion of the flock. If the minimum space and range of interaction were coupled, one could be more or less assured of consistent sonic behavior irrespective of the minimum space.

In both models, the overall "music-space" can be constrained also by the speed of the agents, and in the boids model, the addition of targets and/or obstacles. By adjusting the speed in a direct mapping situation, the agents will travese the extremes of the mapped range more or less quickly. This would function similarly in the coupled approaches as the relative maximum speed would increase. The addition of targets or "attractors" in the flock-space draw the agents to a particular region that is representative of specific sonic characteristics; this particular method of constraint is what we shall see Blackwell's musical paradigm is predicated on. However, this method may work better for a direct mapping situation and has not yet been tested with other mapping strategies.

In my own implementation of the boids algorithm, I utilize an interval time which, when combined with the maximum speed (in meters per second), gives a working maximum speed for a given time interval. That is, if the maximum speed is 10 m/s and the time interval is 0.1 *seconds*, then the working maximum velocity for the purposes of calculation (in a loop that occurs every 0.1 seconds) would be $10 \times 0.1 = 1$ m/s. Thus, the maximum speed of the agents and the calculation loop is decoupled allowing the flock to move in "slow motion" by maintaining the momentum that is gathered in a high speed situation and stretching it out in time by calculating at a slower rate than the interval. This allows "slowness" to be perceptible while maintaining the properties of high momentum which include collision of agents; that is, the ability to overcome mutually repulsive forces.

4. Flocks in Abstract Music-space

Relatively few forays have been made into using flocks in what might be called "abstract music-space"; that is, non-literal-spaitial domains of motion. Those who have documented their work are few and often used their systems exclusively for improvisation.[21] It seems that the inclination toward improvisation is an implicit nod to the ofttimes unpredictability of the behavior of the simulations, as one cannot always ensure that they will remain in the "space" on wishes without severly constraining their behavior and thus threating the collective motion sought. If implemented in a written piece, that is, a piece in which the flock has a part that must be reproducable, this unpredictability can be a liability and threaten the identity of the piece unless an optimal take were recorded in studio and played back in performance.

Below are discussions of two well-documented instantiations of flocking algorithms used in abstract music-space: the first by Tim Blackwell and the second by Cristián

[21] Hembree, Blackwell

Huepe, Marco Colasso, and Rodrigo F. Cádiz. Blackwell's documentation is primarily that of descrbing the systems he uses for improvisation while that of Huepe et al. is a paper that analyzes Cádiz's work *Ritmos Circadianos*.

As mentioned previously, I was able to find no instances of flocking music that was produced in non-real-time; that is, music that was produced by some sort of flocking simulation that was fixed for later performance. This, I imagine, has more to do with the fetishization of "real-time performance" than any broader aesthetic considerations.[22]

4.1. *Tim Blackwell's Swarm Music*

Tim Blackwell uses a derivation of the Reynolds model and removes rule three (alignment) to create agents that move with their own agency in the space. His project is primarily interested in free improvisation both using the collection as an improvising tool (instrument), and interacting with the collection as if it were an independent agent in an ensemble. Moreover, he explicity acknowledges their unpredictability as ideal for improvisation[23] and speaks at great lengths about the concept of, *stigmergy*[24] the biological process by which an organism effects change in its environment that in turn effects change on the behavior of others in the group.

Blackwell speaks of his collections as *swarms*, in the sense that due to the lack of velocity matching, the agents move relatively independent of each other with regard to direction and speed. In each paper published, Blackwell uses swarms of three[25] or five[26] agents, at times using up to two separate swarms simultaneously for each output channel[27] or for upper and lower voices in the piano[28] in independent, but interrelated, Euclidian spaces. The dimensionality of the swarms are between three or, in the case of the swarm in *Self-organized Music*, six dimensions.

A core component of Blackwell's practice is that of positioning "attractors" in the

[22]From an listeners point of view, there is no great benefit in hearing a work produced in real-time that is only superficially distinguishable from any other performance of the same system.

[23]Blackwell, *Swarming and Music*, pg. 1

[24]Grassé, Pierre-P. "Reconstruction of the nest and coordination between individuals in terms. Bellicositermes natalensis and cubitermes sp. the theory of stigmergy: Test interpretation of termite constructions."

[25]Blackwell, *Swarm Music*, §4.1 and §4.3

[26]Blackwell, *Swarm Music*, §4.2, *Swarming and Music*, *Self-organized Music*

[27]Blackwell, *Swarming and Music*

[28]Blackwell, *Swarm Music*, §4.3

flock-space that are representative of an external musical event with such-and-such qualities in a process he calls "interpreting" which functions as a kind of inverse-mapping. That is, in the context of an ensemble, an external musical event is captured and given to the flock as a viable music-space to inhabit which the flock then responds to in likeness of the event (likened with the aforementioned concept of stigmergy). This is done by a process which analyzes incoming sound (or MIDI information) into the dimensions required for embedding into the flock-space being used. The dimensions Blackwell often uses are: pitch, interval (for a phrase), note duration, amplitude, event duration, chord number, sequence number, mode, and tonic.[29] Note that Blackwell does not necessasrily use each and every dimension for each piece but this is merely a list of dimensions he has used. Blackwell likens this process of interpretation and embedding to stigmergy whereby a musical event is used as a change in the flock's environment, prompting behavioral change from the flock itself. This is a quite interesting and useful paradigm for working with flocking simulations in real-time improvised settings.

Another feature of Blackwell's music is his use of two simulations simultaneously as demonstrated in *Self-organized Music*. In two swarms, A and B, there are five agents which move according to the Reynolds model. They interact with each other by positioning attractors mutually, placing the position of their own agents as attractors in the other; that is, agents in A are made into attractors in B and visa versa. In the paper, Blackwell then shows the stigmergetic interaction between the two swarms as they are attracted to parts of the other in their own flock-space: "The result is that a movement of the note component of the centroids of each swarm show a similar pattern."[30]

4.1.1. Discussion

It's said that two's company and three's a crowd; so then, according to Blackwell, five's a swarm? This seems dubious at best and I challenge anyone to point to a swarm consisting of only five agents. The idea of a swarm conjures up something

[29] All Blackwell's papers
[30] Blackwell, *SoM*, pg. 133

large and massive, where individuals are indistinguishable and only broad contours are perceptible. Describing a collection of five agents as a swarm is beyond optimistic and borders on misleading. Perhaps Blackwell simply means to say that these agents exhibit swarm-like properties. This, too, is problematic: properties of a swarm arise from the collective behavior of many agents acting within an environment. The properties are "meta-agent", in that no individual posseses characteristics that the whole posseses. This is consistent with the concept of emergence, whereby properties in a collection are not found at the individual level but are only seen at a level beyond. Blackwell himself seems aware of this when he says "[m]eaning itself can only emerge, and is only apparent at, the next highest level,"[31] and is perhaps suggesting that the agents become a swarm in the next highest level, i.e. when they become sound. But again, five agents does not a swarm make and this is especially the case when there is only a subset of the five that are making sound.[32]

The parallels Blackwell draws between improvisation in an ensemble between actors (human or machine) and the internal processes of a swarm are indeed interesting. In fact, this conception of an improvising ensemble with stigmergy, action, and feedback would make Norbert Weiner, the father of cybernetics, shed a small but happy tear. The processes of embedding musical events into the flock-space is a clever solution to ensuring that an improvising swarm maintains cohesiveness with the ensemble and does not have the ensemble chasing its indeterminate nature as it explores the music-space oblivious to its own contribution. It would be interesting, though, to design some sort of "check" with which the flock could decide whether or not it "likes" the musical event it has been given and could possibly reject it or alter it in some way before embedding. In this way, the swarm would have an *aesthetic sensibility* which the current implementation defers to the human players. I imagine this could be accomplished with a fitness function for the swarm as a whole.[33,34]

Regarding the stigmergetic interaction between two separate swarms, their similar

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[31] Blackwell, *S&M*, pg. 8

[32] The obvious solution to the miniscule size of the swarm is to have a swarm of, say, 50 agents and then select a subset of five agents to follow.

[33] A fitness function is a way of determining how well a dynamic system, often in genetic algorithms, fulfills a set of goals.

[34] While Blackwell does have published literature on swarm optimization, it does not appear to be applied to musical examples and was thus not reviewed for this text.

motion is unsurprising given the nature of the attraction functions in the Reynolds model. However, this appears to be the functional equivalent of a single swarm composed of ten agents and unless the specific paramaterizations of each swarm is appreciably different, it does not seem that this method would yield anything different than a double-sized single swarm. Even if the two swarms were appreciably different in their parameterizations, there is nothing in Reynolds model that precludes different application of the same rule to different agents in the same swarm. For instance, each agent could have an independent maximum speed or minimum space without compromising the integrity of the algorithm. If the biological metaphor is indeed what is sought after, this inequality between agents would be an even greater reflection of a species population.

Additionally, there are some questionable generalizations made in an effort to validate this approach. For instance in speaking of what makes music *music*, Blackwell argues that "higher-level strucutres" in music such as melodies and rhythms can be a result of self-organization of musical tones when the tones are considered "to be simple individuals interacting with neighboring tones through simple rules."[35] Is that a fair characterization of music, that it is merely a higher-level structure of interacting tones? The answer to that particular question is left to the reader.

Regarding the specific musical behavior of the agents in abstract music-space as melody-creating entities, Blackwell claims that the so-called swarming behavior "leads to melodies that are not structured according to familar musical rules, but are nevertheless neither random nor unpleasant."[36] It seems that the standard of "neither random nor unpleasant" is so low that it carries no meaningful value and that there need not be such an elaborate conceptual and technical framework in order to clear that bar. Further, it is also unclear how Blackwell is interpreting "familar musical rules" since if the interpretation of events (the process of embedding into flock-space) were performed accurately, the internal musical logic of the event ought to be reflected in the musical output of the swarm. To put it in the reverse, if the swarm were given an event that adheres to "musically familiar rules", the output of the swarm ought

[35] Blackwell, *SoM*, pg. 124
[36] Blackwell, *SoM*, pg. 124

to abide by these same rules so as to ensure the output of the swarm is a function of the properties of the embedded *event* and thus musicality, and not a function of the swarm behavior regardless of input.

4.2. *Cádiz's Ritmos Circadianos*

At the end of Christián Huepe, Marco Colasso, and Rodrigo Cádiz's study, a study of Cádiz's work *Ritmos Circadianos* for robot orchestra is presented. The pieces uses the Vicsek model and associates the twelve instruments of the orchestra with a single agent in a twelve agent flock. The pitch material for each instrument uses the coupled oscillator approached outlined in the paper and is quantized to equal temperament and converted to fit each instrument's range. That is, whenever the agents (instruments) are coupled, their pitches will remain relatively stable; however, the ranges are not mapped equally which implies that the stable pitch of a given instrument is not necessarily the same as another instrument. This is because the output of the frequency value from each agent is normalized to be between $0-1$ before it is mapped onto a particular instrument, with 0 being the lowest possible note and 1 being the highest. This frequency value between 0 and 1 is referred to in the next section as the pre-quantized, pre-scaled frequency value.

Rhythmically, each instrument is associated with up to three independent pulses (the nature of which are specified by the composer and not detailed in the paper) and are rescaled according to its pre-quantized, pre-scaled frequency value (0 to 1). Moreover, the main pulse is tied to the absolute value of the difference between a specific agents heading angle and the average heading angle of all the other agents such that the higher the difference, the higher the irregularity of the pulse; i.e. the coupled approach. This means that the pulses are scaled two-fold: once by the pre-quantized, pre-scaled frequency, and second by the difference of heading. Amplitude is determined by the agents (instruments) distance from the origin of the flock-space such that as the origin is apprached, amplitude increases. These together create various poly-rhythmic dynamics and harmonic textures at different stages of the piece.

Structurally, the piece moves through 26 different 24" sections, each with a different set of paramaterizations of the twelve agent Vicsek model. This gives rise to differences in harmonic and rhythmic quality while moving through the different sections. Each performance is generated in real-time by creating a MIDI score that is passed to the instruments as opposed to being played back.

4.2.1. Discussion

While one can generally hear the transitions between various states of the model, it is not clear that the piece is successful in translating the flocking behaviors that appear so clearly visually to sonic entities. None of what is heard sounds particularly like "flocking" or emergent properties and if listening in ignorance (that is, listening without knowing where the structure comes from), it is doubtful that a listener would ascribe "flock-like" to the piece's sound. Moreover, there is what appears to be a lack of a harmonic language due to the way pitch is derived. Using the coupled oscillator approach is interesting, to be sure, but the result ends up being more amorphous than coherent. If clustering in the same direction is stability across agents, the stability is rendered invisible in the collevtive as the stable pitches for each instruments are different and there may be only one instrument playing at that moment. If, say, the stable pitches were the same or were in a simple chord, it might, then, be more apparent that the agents had reached a "consensus" amongst themselves.

In the sections in which one or a few instruments are playing, it is unclear whether or not they are allowed to interact with instruments' agents that are not playing. If it is the case that the non-playing instruments are "allowed" to interact, a twelve agent flock seems quite small, especially since it would then not be conceptually dissonant to allow interaction with invisible members. Indeed, one might find that the behavior is more complex and coherent with more agents, even if some of those agents were "invisible".

Lastly, it is not clear why a flocking simulation was used in the work apart from technological novelty which is, as far as I am concerned, not a particularly strong reason.

5. Creative Considerations

It seems the biggest hurdle is that, intuitively, one wants the flock to sound as it appears visually; this is especially the case with regarding flock-like spatialization of electroacoustic sound and is reflected in the goals of the study conducted by Huepe et al. and the way in which Blackwell speaks about his work. Tom Davis and Pedro Rebelo argue that the one-to-one of direct mapping is not actually a mapping of the qualities found in emergent systems but rather a "sonification of primarily graphic systems rather than the design of emergence in the sound domain."[37] This is the central problem. It is easy to ask what a flock looks like but the question we are concerned with is: what does a flock *sound* like? What does it mean for a sounds to be "clustered"? I imagine it essentially means that a set of sounds would reside "close" to one another in some musical dimension such as pitch, amplitude, or timbre. But this could only be observed if a minimum number of agents were voiced at the same time since "closeness" is necessarily a comparative term. What seems critical is the ability to hear the clusters that form in both the Reynolds and the Vicsek models in some way as "musical closeness".

The question is then: can flock-like behavior be perceived when one does not necessarily observe all of the agents? This is a critical question for a musical application since it is natural for some sound making entities to be silent at times (to rest, in the traditional musical lexicon). These are built-in degrees of freedom of music that are not necessarily present in a graphical representation of a flock. Perhaps the problem with mapping is that one wants it to sound like it looks *all the time* but due to the nature of music, with its rests and varying densities, it will only appear as a flock *some of the time* and in *some projections*. The situation seems more akin to a flock in a dark room with no reflective surfaces in which one possesses a flashlight with a variable beam. The beam can be very focused or wide but not all the members of the flock will necessarily be lit up at any given instant since once can only turn one direction at a time.

It could also be the case that each of these pieces, and the work for each study on

[37] Davis, Thomas, and Pedro Rebelo, "Hearing emergence: towards sound-based self-organisation", pg. 1

mapping, used a flock that is far too small. Perhaps what the ear needs is a greater stimulant, say, 100 agents that are made initially more diverse so that convergence can be more clearly heard. This creates other problems, of course, but none that could not be mitigated with clever programming or the relenquishing of "real-time" performability.[38] A larger and related question is whether something that appears beautiful and interesting visually can be translated to the aural world with convincingly similar properties or whether visual phenomena are aurally interesting. Perhaps, one might answer, we are unconcerned with a "faithful" reproduction of such visual phenomena aurally and rather wish to exploit its properties. However, this can only be said if one knows the answer to the question regarding distinguishability between similar mathematical processes in aural-space.

The question at last arises: is all this overhead worth it? That is, can these properties actually be heard *and* distingushed from other similar processes such as Markov chains or Brownian motion? If so, under what conditions? That seems to be a study worth pursuing, lest we prefer to live forever in nympholepsy. The question was asked what sort of behaviors are flocking simulations capable of but a more pointed question is to ask: what sort of behaviors are *unique* to flocking simulations, can these behaviors be heard and, moreover, are these useful for aural artforms in ways that similar processes are not? As the analysis of the two examples demonstrated, it is at present a questionable practice as neither work created sonically convincingly flock-like (or swarm-like) behaviors.

[38]See Appendix A for more on "Computational Considerations"

Pseudocode 1. Reynolds' Boids

Each of the below algorithms are each rule as performed *for each agent*. That is, this is performed on each agent in a simulation. Generally, there is a zero vector equal to the number of dimensions in the simulation that acts as a placeholder for the change in velocity. All velocity operations add/subtract to that zero vector which is then added to the agents *actual* velocity when it is ready to be moved.

```
Algorithm 1: Boids Implementation
  Input: A single agent, A_i
  v = a zero vector;
  v = v + (the output of Rule 1);
  v = v + (the output of Rule 2);
  v = v + (the output of Rule 3);
  add v to the previous velocity of A_i;
  add the velocity to the postion of A_i;
```

```
Algorithm 2: Boids Rule 1 - Center Seeking
  Input: A single agent, A_i, a set of all agents, A, a range of attraction
  for each agent in A, A_j do
  |   if A_i is not identical with A_j then
  |   |   dist = the Euclidian distance between A_i and A_j
  |   |   if dist < range of attraction then
  |   |   |   add A_j to a list, L, of neighbors of A_i
  |   L_avg = the average positon of the agents in L
  |   add L_avg to the velocity placeholder of A_i
  end
```

```
Algorithm 3: Boids Rule 2 - Separation
  Input: a single agent, A_i; a set of all agents, A; a range of avoidance
  v = a zero vector
  c = 1; // a counter
  for each agent in A, A_j do
  |   if A_i is not A_j then
  |   |   dist = the Euclidian distance between A_i and A_j
  |   |   if dist < range of avoidance then
  |   |   |   diff = the difference of the positions of A_i and A_j;
  |   |   |   subtract diff from v;
  |   |   |   c++; // incremenet c
  end
  v = v/c; // scale v by c
  add v to the velocity placeholder of A_i
```

Algorithm 4: Boids Rule 3 - Alignment

```
Input: A single agent, A_i, a set of all agents, A
for each agent (A_j) in A do
    if A_i is not identical with A_j then
        dist = the Euclidian distance between A_i and A_j
        if dist < range of attraction then
            add the velocity of A_j to a list of neighbors of A_i called L
    get the average velocity of the agents in L, L_avg
    add L_avg to the velocity of A_i, generally by a fraction of the whole
end
Result: A new velocity for A_i
```

Pseudocode 2. The Vicsek Model

Algorithm 5: Vicsek Agent Update Function

```
Input: a single agent, A_i; a set of all agents, A; a fixed velocity, V
averageHeading = 0;
count = 0;
for each agent (A_j) in A do
    if A_i is not identical with A_j then
        dist = the Euclidian distance between A_i and A_j
        if dist < range then
            averageHeading = averageHeading + the heading of A_j;
            count++;
    divide averageHeading by count to get the actual average;
    add noise to averageHeading;
    get a unit vector U which points in the direction of averageHeading;
    scale U by the fixed velocity V add U to the position of A_i
end
```

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Appendix A. Computational Considerations

In my own experiments, running a large flock in several dimensions with multiple targets and obstacles is quite costly for real-time usage, even on a very fast machine. However, since many flocking algorithm implementations do *not* use randomness (i.e. the systems are fully deterministic), one could ostensibly create an archive of positions at time values t, such that the values would simply be read back in performance or rendering. This, of course, is problematic in improvisational music but if one were, say, creating fixed media the issue of whether or not the flock was calculated in ”real-time” during recording is non-existent for the listener.

QUALIFICATION QUESTION #3

So Wiener, Burnham, and Tudor walk into a bar...

Jacob Sundstrom

QUESTION

Anthony Burr

You have been looking at the history of the use of concepts derived from cybernetics in art practice and the emergence of whats been termed systems aesthetics". Present an overview of this history paying attention to both the creation of art directly via technologies and the adaptation of conceptual structures from cybernetic thought to art practice. In addition to this overview, present a detailed analysis of one or more works by a major figure (or figures) in some detail.

1. Introduction

> "Use the word 'cybernetics', Norbert, because nobody knows what it means. This will always put you at an advantage in arguments."
>
> - attributed to Claude Shannon in a letter to Norbert Wiener[1]

Even the American Society for Cybernetics, ostensibly the institutional authority on cybernetics, offers no fewer than **forty-six** definitions of cybernetics as offered by various thinkers, artists, and scientists associated with the field. Among them, in no particular order:[2,3]

- "The science of control and communication in the animal and the machine" (Norbert Wiener)
- "[Cybernetics] tries to show that mechanisms of a feedback nature are the base

[1] "Definitions." *American Society for Cybernetics*
[2] "Definitions." *American Society for Cybernetics*
[3] Broekmannm, *Machine Art in the Twentieth Century*, pg. 101

of teleological or purposeful behavior in man-made machines as well as in living organisms, and in social systems.” (Ludwig von Bertalanffy)

- “Cybernetics treats, not things, but ways of behaving. It does not ask, ‘What is this thing?’ but ‘what does it do?’ ” (W. Robert Ashby)
- “Should one name one central concept, a first principle, of cybernetics, it would be circularity.” (Heinz von Förster)
- “Cybernetics is the awareness of the process that keeps phenomena in balance.” (Nicolas Schöffer)
- “The ability to cure all temporary truth of eternal triteness.” (Herbert Brün)

The ambiguity of Herbert Brün’s definition is particularly delightful, even if it seems his faith in the strength of a single branch of science is questionable. So, then, what is cybernetics? For the purposes of this text, it will be aligned most closely with Wiener and von Bertalanffy’s definitions above but, as one will see, this is never quite so clear cut. Nonetheless, once cybernetics took hold in the disciplines of mathematics and physiology after the publication of Wiener’s book *Cybernetics: control and communication in the animal and machine* in 1948, it found its way into biology, engineering, and eventually the arts. It is perhaps because of the wide application of the term that it gathered such diverse definitions that, although implying different perspectives, never contradict one another.

Heinz von Förster said it best: “That is the fascinating thing about cybernetics. You ask a couple of people to give you a definition and although you don’t get to know much about cybernetics from them, you find out a lot about the person supplying the definition, including their area of expertise, their relation to the world, their desire to play with metaphors, their enthusiasm for management, and their interest in communications or message theory.”[4]

This paper will present a brief historical overview of Norbert Wiener’s cybernetics, as well as its conterpart systems aesthetics found in the writing of sculptor and art theorist Jack Burnham. As a locus, it will use David Tudor’s *Bandoneon! (a combine)*, first performed at the *9 Evenings: Theatre & Engineering* in 1966 with help from Fred Waldhauer from Bell Labs. It will not serve as a technical analysis of the piece but

[4] “Definitions.” *American Society for Cybernetics*

rather present it as an early instatiation of the concepts found in both cybernetics and systems aesthetics of which technical production is a crucial component.

2. Cybernetics and Systems Aesthetics: an Overview

It is not the purpose of this paper to provide a detailed summary of either cybernetics nor systems aesthetics, but rather to show their relationship to one another and their manifestations in artwork. However, having at least a cursory understanding of both is critical for the discussion that follows; thus, a brief overview.

2.1. *Cybernetics*

The word “cybernetics” often conjures up images of machines — machines plugged into machines, machines plugged into humans, a cyberpunk-like orgy of cables, sweat, electricity, and blood.[5] According to Merriam Webster, cybernetics is defined as ”the science of communication and control theory that is concerned especially with the comparative study of automatic control systems (such as the nervous system and brain and mechanical-electrical communication systems).”[6] It is, essentially, the study of systems as they appear in animals and machines, and is a precursor of sorts to Ludwig von Bertalanffy’s general systems theory which greatly influenced Jack Burnham’s thoughts on systems aesthetics.

The term itself originated in Norbert Wiener’s 1948 book *Cybernetics: or control and communication in the animal and machine*. In this seminal text, Wiener coins the term cybernetics and lays out what he sees as the tennants of the field. Of the word, Wiener constucted it from the Greek for *steersman*: ”We have decided to call the entire field of control and communication theory, whether in the machine or in the animal, by the name *Cybernetics*, which we derive from the Greek $\chi\upsilon\beta\epsilon\rho\nu\eta\tau\eta\zeta$ (kybernetés) or *steersman*.” While Wiener acknowledges the fact that application of the specific term cybernetics does not predate 1947, the concepts it embodies surely predate the term and were touched on by Clerk Maxwell and his article on *governors*

[5] One can dream...
[6] “Cybernetics.” *Merriam-Webster*

in 1868.[7]

The aspects of cybernetics this text will primarily concern itself with are:

- feedback
- information
- interdisciplinarity

2.1.1. Feedback

Perhaps the most important concept in cybernetics is that of feedback, wherein information from the output is in some proportion added to the input before being recalculated. If there is no feedback in a system, it cannot be responsive and would thus have no information about the way in which its environment has changed, either by its own action or those actions precipitated around it by something else. Critically, the nature of the information contained in the feedback is based on its actual performance at any given moment, not its expected performance at that same moment.[8]

Wiener provides the example of picking up a pencil. This action is performeds automatically by the "will" in that one does not deliberately and consciously contract, to a specific amount, the specific muscles needed to pick it up. How, then, is this accomplished without thereby overshooting or undershooting the object? There must, according to Wiener, "be a report to the nervous system... of the amount by which we have failed to pick up the pencil at each instant."[9] Further, the "motion is regulated by some measure of the amount by which it has not yet been accomplished."[10] This report is visual (assuming the lights are on and our eyes are open) but is more generally proprioceptive; that is, kinesthetic in nature. The information which is gathered by the nervous system is *feedback* and the brain responds appropriately. Feedback, however, need not be the domain of a highly complex system such as the human body or that of a guided missle system but can be mechanically induced by the simple thermostat found in a home. This device operates by virtute of its "sense organ" that is solely thermoceptive: a two-sided band of metal expands and contracts with the temperature.

[7] Wiener, *Cybernetics*, pg. 11
[8] Wiener, *Human Use of Human Beings*, pg. 12
[9] Wiener, *C*, pg. 7
[10] Wiener, *C*, pg. 97

It is the responsibility of the thermostat to "check" where the temperature is and to respond accordingly, either by turning on in the case of too low a temperature, or by turning off, when the temperature has reached a sufficiently high level.

From the idea that feedback is the proportion of that which has not yet been accomplished, it follows that feedback, in this instance, must be negative; that is, it opposes what the system is already doing and thus serves to stabalize the system. This stability also known as *homeostasis.* The question begs: what happens when the level of feedback is insufficient than what is necessary to stabalize the system? How does the system respond?

2.1.1.1. Oscillation or "hunting". Oscillation, or what Wiener calls *hunting*, is a natural consequence of feedback in a system. Specifically, oscillation occurs when feedback is insufficient to stablaize the system or is positive in nature, reinforcing what the system is already doing (and thus underminding stability). To return to the physiological example in the previous section, this is appears as *ataxia.* That is, the feedback from the eyes and proprioceptive sense are blunted and the brain overshoots the amount needed to give the correct result which then it attempts to correct by moving in the other direction at least as hard, which follows... the idea is clear. The same phenomenon accounts for fishtailing, in which a driver overcorrects a skid by steering in the opposite direction too far which then swings the rear end of the vehicle back even further which is overcorrected yet again. This can also appear in circuits and is primary feature of Tudor's *Bandoneon!* as will become clear later in the text.

2.1.2. Information

Through the lens of cybernetics, information is viewed as messages between systems or between components of a system that are used as input to another system. Indeed in Wiener's *The Human Use of Human Beings*, a great majority of the book is concerned with the idea of communication and its essentiality to the nature of man and society. Cybernetics itself is the study of the "effective messages of control."[11] Information is organized into *patterns*[12] which are *negentropic* in nature; that is, patterns resist

[11]Wiener, *HUHB*, pgs. 3-9
[12]Wiener, *HUHB*, pg. 4

entropy.

2.1.2.1. Entropy and Negentropy. A measure of the information present in a system at any given time is a measure of the *order* of the system and its negative is a measure of the *disorder*. In cybernetics, these are known as negentropy and entropy, respectively. Wiener further argues that entropy "almost never spontaneously decreases in an isolated system"; that is, there is a natural tendency toward disorder which, contrary to popular myth, is also a tendency toward equilibrium.[13] Incidentally, this is the second law of thermodynamics applied to communication systems. Note that being able to measure the entropy of a system demands that the information contained within the system is quantified. This in particular presents a potential problem when applying the notion of information to the arts.

2.1.3. Interdisciplinarity

While not a technical aspect of cybernetics, it is, nonetheless, an important qualitative feature. Cybernetics, as conceived by Wiener, helps to navigate the no-mans-land between disciplines and the places where the boundaries are no so distinct as they might be elsewhere.[14] The thing to note here, though, is that it is not interdisiplinary between any particular fields but it rather comes to being in those murky spaces just described.

2.2. *Systems Aesthetics*

Introduced by Jack Burnham in his article *Systems Aesthetics*, systems aesthetics is essentially an application of the concepts of general systems theory found in the writing of Ludwig von Bertalanffy to artwork and the art world in general.[15] He goes so far as to quote von Bertalanffy directly in defining a system as "a complex of components in interaction..." The principles of systems aesthetics are three-fold: environmentality, interactity, and autonomy. That is, environmental in the sense that the bounds of the artwork are no longer the physical bounds of the object; interactive in the sense that

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[13]Wiener, *HUHB*, pg. 19
[14]Wiener, *C*, pg. 2
[15]Burnham, *Dissolve into Comprehension, Systems Aesthetics*

the artwork is a system of interactions; and autonomous in that the "viewer does not control the meaning, but witnesses it."[16] Though Andreas Broeckmann takes autonomy to be more figurative, systems aesthetics does not preclude the *literal* autonomy of an artwork, wherein the apparatus of the artwork can almost be ascribed its own personality.

Burnham cites the changing societal needs during the 1960's, shifting away from "products", that is, "filling consumer needs on a piecemeal basis" where the objects of technology strucutred the patterns of living, toward concerns such as "maintaining the biological liviability of the earth, producing more accurate social models of interaction, understanding the growing symbiosis in man-machine relationships, establishing priorities for the usage and conservation of natural resources, and defning alternate patterns of education, productivity, and leisure." This, he argues, demonstrates a "transition from an *object-oriented* to a *systems-oriented* culture. Here change emanates not from *things*, but from the *way things are done*."[17] This sentiment was echoed decades before by the philosopher Alfred North Whitehead in *Process and Reality* when he said that it was processes, as opposed to substances, that constituted the world.[18]

Fundamentally, systems aesthetics works from the notion that the function of modern art "has been to show that art does not reside in material entities, but in relations between people and betwen people and the components of their environment."[19] That is, the object itself serves as a *catalyst* for exposing these people-people and people-environment relationships as the constituents of art and *not* the superficial appearances present in the object. This, of course, applies too to sound art such as music. This idea is made concrete by Burnham's example of Robert Morris' work at the 1966 "68th American Show" at the Chicago Art Institute. Morris had created two large, L-shaped strucutres that were shown the previous year in New York City. When the work was to be installed in Chicago, it was found that it was cheaper to send plans for the work to be rebuilt in Chicago than it would be to ship the originals from New York. Burnham: "In the context of a systems aestethic, possession of a privately fabricated work is no

[16]Broeckmann, *MATC*, pg. 107
[17]Burnham, *DiC, SA*, pg. 116
[18]Whitehead, *Process and Reality*
[19]Burnham, *DiC, SA*, pg. 118

longer important. *Accurate information* takes priority over history and geographical location."[20] (Emphasis added)[21] Were there any complaints from visitors to the "68th American Show" that Morris' work was not a true "Morris" since he himself did not lay hands on the piece? If there were any, none were recorded in the historical record. In the words of Burnham, again: "In such handling of materials the idea of *process* takes precedence over end results."[22] (Emphasis original)

Burnham further suggests that a systems approach in art deals with the problem of "boundary concepts". Traditionally, it is the material limits of an artwork that define it as such; that is, they enclose the system by placing it in a frame or on a stage. From a systems perspective, however, it is the "conceptual focus rather than material limits that define the system."[23] Because of this shift from the material to the conceptual, from the object to the system in which the object resides, the information contained in and about the art object becomes a "viable aesthetic consideration." If the material object is thereby denied an ability to define the boundary conditions of itself as an artwork and that it is the relationships which it exposes and in which it sits that define it as such, then it follows that the fetish character of the "high art" object is called into question. Les Levine's *disposable* and *infinite* series make this manifest in the mass production and distribution of art objects, thus "deny[ing] scarcity as a legitimate correlative of art."[24] Moreover in the systems approach, both interaction and the autonomy of a work become important and desirable considerations since, as opposed to formalist art where the relations betwen a works *visible* elements are foregrounded, *invisible* relations are brought into aesthetic consideration.

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[20]Burnham, *DiC, SA*, pg. 120

[21]It is interesting to consider this example in particular with regard to music. In the classical music tradition, there are no qualms about a composer who originally performed their own works being absent from a performance of the same work at a different time. That is, their (un)presence does not necessarily add anything to the artwork that is transmitted to the ears of the listeners. This is not true, though, in the case of "cover bands". Perhaps this is more a function of temporal proximity or even availability of the "originals", even in old age and inferior performance, than it is about the specific notions of the art flowing through the air.

[22]Burnham, *DiC, SA*, pg. 120

[23]Burnham, *DiC, SA*, pg. 118

[24]Burnham, *DiC, SA*, pg. 122

2.3. *Cybernetics + Systems Aesthetics in the Arts*

As one might naturally suspect, the ideas codified in both cybernetics and systems aesthetics were present in the work of artists long before either Wiener or Burnham put them in writing. As early as 1925, the Hungarian artist László Moholy-Nagy imagined "simultanous, synoptic, synacoustic (optical or phonetically mechanical) representation[s] of thought (cinema, gramophone, loudspeaker) or a design of thoughts that interlock like cogs,"[25] These notions of interlocking elements assembled from various disciplines, this inter-domain feedback and communication is the backbone of cybernetics. In his *Light Prop for an Electric Stage* (1930), Moholy-Nagy created a rotating kinetic scupture using motors, metal, and electricity in order to "demonstrate the effects of light and movement."[26] The interconnected nature of the various systems used in the piece — both mechanically and conceptually — are clear forerunners of the cybernetic impulse. Despite the aesthetic intent of the piece, it is interesting to note that Moholy-Nagy speaks of his work as *demonstrating* something relatively objective: that of the formal relationships between the viewer, light, and movement. One may argue that indeed the entire project of systems aesthetics is to lay bare the relationships found within, betweeen, and amongst an interdisiplinary artwork and its context.

More explict in the usage of cybernetic principles are the sculptures of Nicolas Schöffer where his goal was the "total liberation of sculpture" in a practice he called Spatio-Dynamism by creating "kinetic scuptures whose movements are not predetermined and that [stand] in a dynamic relationship [to] its environment."[27] Schöffer had read the work of Norbert Wiener in the 1950's and described cybernetics as "the awareness of the process that keeps phenomena in balance," and that in an aesthetic context of this balance, "every appearance of a tendency toward periodicity or stagnation triggers the intervention of the perturbations needed to maintain the openness and the contingent character of any evolving process."[28] Schöffer's *CYSP 1* from 1956, a piece he considered to be the first work in which the principles of Spatio-Dynamism were applied in their totality, was later exhibited in 1968 at Jasia Reichardt's show

[25] Broeckmann, *MATC*, pg. 100, note 43
[26] Shanken, Edward A. *Art and Electronic Media*, pg. 18. Moholy-Nagy quoted from The New Vision, 1928
[27] Broeckmann, *MATC*, pg. 98
[28] Broeckmann, *MATC*, pg. 101

Cybernetic Serendipity, one of the first attempts at an overview of work produced by artists inspired by cybernetics and systems theory. As Andreas Broeckmann argues, *Cybernetic Serendipity* was "an art show as much as a demonstration of new technologies and cybernetic principles."[29] It is curious that in *Cybernetic Serendipity*, nearly all aspects of research in the field of computer music were included as part of the music portion, pointing to the cybernetic origins of computer music as we understand it today. This, of course, is not strictly due to the technological requisites of the practice but to the type of thinking endemic to computer music since its birth.

Systems aesthetics, as oulined by Jack Burnham, was a parallel development to cybernetic aesthetics was the aforementioned. Once again, enter László Moholy-Nagy: his 1923 piece *Telephone Pictures* prefigures the supremacy of information as the subtance in an artwork in the view of systems aesthetics. In 1970, Burnman curated the show *Software* that, among other things, showcased work that embodied the principles of systems aethetics as the "art impulse in an advanced technological society."[30] It is interesting to note that until as late as 1997, art historian Marga Bijvoet noted that despite the acceptance of systems theory and cybernetics as valid approach methods in various disciplines, the scholarly art world has generally neglected this approach. This despite the fact that artists have been explicity creating cybernetic work and enganging directly with the ideas found in Burnham's systems aesthetics since their conception including Nam June Paik, Hans Haacke, and Les Levine, apart from those already mentioned.

But what of music? Nearly all of the musical works that were included in *Cybernetic Serendipity* would be considered "traditional" computer music in the present day. Their defining feature was that of using computers and technology to enable and aid the compositional or analytical process. While relevant, these are not exactly the kind of projects this text seeks to focus on. Many years afterward there emerged on the periphery of the already obscure practice of electronic music a figure who directly engaged with these cybernetic principles both explicity and conceptually.

[29] Broeckmann, *MATC*, pg. 103
[30] Burnham, *DiC, SA*, pg. 121

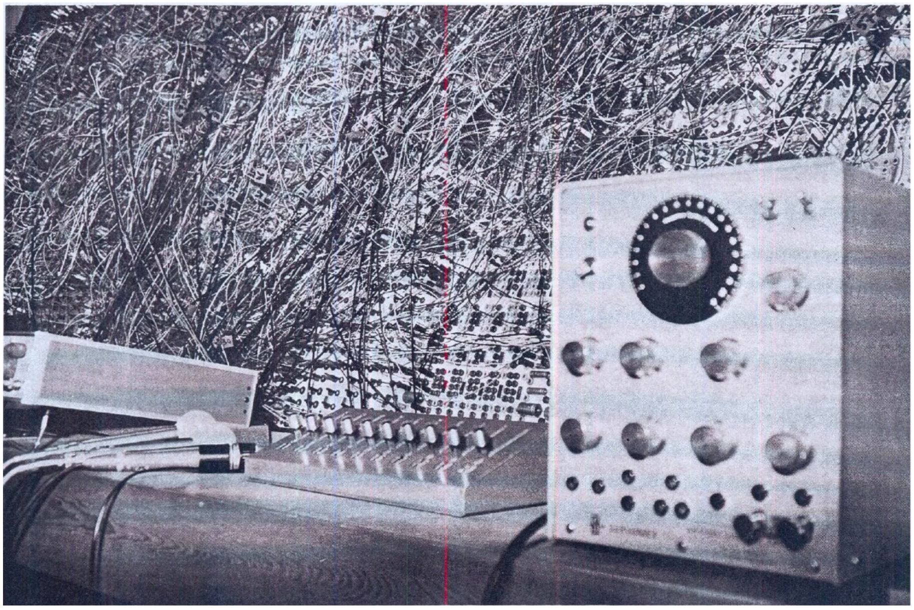


Figure 1. One of Roland Kayn's modular synthesizers.

2.3.1. Roland Kayn's Cybernetic Music: Programming of the Unprogrammable

The music of German composer Roland Kayn is one of the few musics that directly and explicity engage with the concepts and principles found in cybnernetics. His interest in pursuing cybernetics as a compositional approach occured following his study with the philosopher Max Bense and commenced after his relocation to the Netherlands to take a position at the Institute of Sonology. Kayn himself describes his music this way: "Cybernetic music — whether it is produced vocally, with instruments or electronically — is not initially 'composed' and practised. It arises from the interplay of merged control loops setting a process into motion."[31]

Kayn contrasted his work with more "traditional" computer music in that in traditional computer music, a composer generally translates their thoughts into a programming language while in his version of cybernetic music, the "existing sound materials are fed back upon themselves in order to create deviations from that which came before."[32] The result was that the "scores" ended up as "material-technological" configurations of analog devices, the combinatory nature of which determined the space of the work. The very nature of the analog devices Kayn used in his work precluded the determinism of symbolic notations or programmed pieces, instead relying on their

[31]Kayn, "Text"
[32]Kayn in *Infra*, as quoted in Patteson

imperfections to “guide” or “steer” in what Thomas Patteson calls the “etymological spirit of cybernetics.”[33]

In the same way we shall see the technological apparatus of *Bandoneon! (a combine)* possesses its own primitive artificial intelligence due to the number and nature of interconnections, so too Kayn argued that electronic systems possessed a “sort of capacity to think for [themselves].”[34] Moreover, Kayn felt that the self-generative nature of the formal developement in his work was mirrored in the listening process. By bringing the control strucuture “within the range of audibility,” the listener is able to follow the compositional process as it is carried out by the sound-producing devices and “‘the acoustic construct is hence made more lucid and more of a total auditory experience...”[35] Unfortunetly, it is only possible for this text to ascertain Kayn’s thought process from secondary sources, as much of his writing is unavailable or appears in the liner notes of the LP’s he released throughout his life, all of which are rare and out of print.

2.3.2. 9 Evenings: Theatre & Engineering

The entire premise of the *9 Evenings: Theatre & Engineering*, staged at the 69th Regiment Armory in New York City, was to foster collaboration between artists and scientists at Bell Labs wherein both groups would have “an equal voice in the direction and all responsibility would be shared jointly.”[36] By putting the artists and engineers together at the earliest stages of a works conception, organizer Billy Klüver was interested in seeing how works would develop. This act, by its very defintion, is interdisiplinary and thus sets the stage for the works to become cybernetic. Does this mean, then, that all the works at the *9 Evenings* are cybernetic by their interdisciplinary nature? While they may all be considered cybernetic by virtue of their use of various disciplines and/or feedback systems, their interdisciplinarity does not, in and of itself, make them cybernetic.

However, in order to expose how the underlying concepts might manifest themselves

[33] Patteson, *The Time of Roland Kayn’s Cybernetic Music*
[34] As quoted in *Elektroakustische Projekte* in Patteson
[35] Kayn as quoted in Patteson
[36] Klüver’s intro to the catalog as quoted in Morris

in a work of art, it is worthwhile to examine one work in particular: that of David Tudor's *Bandoneon! (a combine)*. Being the most technically elaborate setup of the *9 Evenings* — using devices for sound, visual projections, lights, and kinetic scuptures — it is a prime candidate to examine these concepts both technically and conceptually.

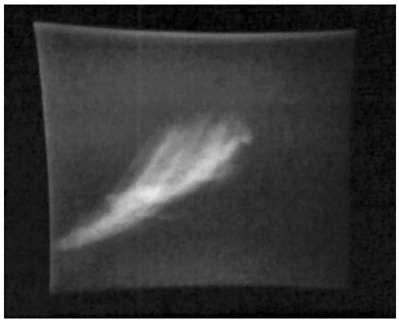
3. David Tudor's *Bandoneon! (a combine)*

David Tudor's *Bandoneon!* (pronounced "bandoneon factorial") was performed twice during the *9 Evenings*, first on October 14 and then on October 18, 1966. While the bandoneon sits centrally (literally and conceptually) in the work, it properly consists of several parts: the bandoneon with ten contact microphones; various electronic sound-producing devices including modulators, distributors, and amplifiers into which the sound of the bandoneon was routed, including the forty-channel Vochrome; twelve independent channels of sound projection (and twelve loudspeakers, one for each channel, distributed about the Armony); visual projections from Lowell Cross' TV Oscilliscope; eight light projectors; five radio-controlled mobile sculptures that moved about the space by operators being vibrated with signals from the bandoneon; and, not least, the Armory as a resonating body itself. An important addition to the bandoneon was a reset button by which the output from the Vochrome could be reset and would thus stop all sound, apart from the natural reverb in the Armony, almost instantaneously.

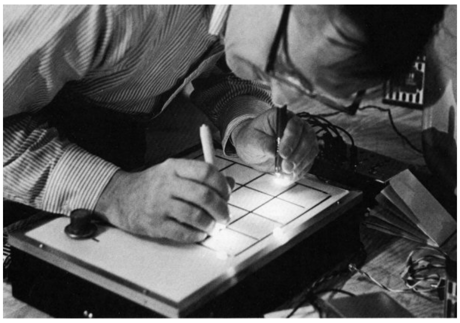
The technical needs of *Bandoneon!* provided an enormous strain on the engineers: "As Tudor played, ten conctact microphones picked up the sound, which was then distributed into four processing devices. The output of a forty-channel filter [the Vochrome] was fed into twelve speakers, and controlled spotlights on the balcony. An audio processing and modifying circuit built by Tudor fed four transducers attached to wood and metal strucutres and horn speakers on the Armory floor [the radio-controlled sculptures]. A fourth device, designed by Lowell Cross [TV Oscilliscope], controlled abstract images on three modified television projectors."[37] This description gives a very rough idea of what was occuring and Herb Schneider later wrote: "Those first two evenings of performances we were plugging in more wires at

[37] Morris, *9 Evenings Reconsidered*

(a) The Vochrome open exposing the row of harmonium reeds.



(b) The TV Oscilliscope during *Bandoneon!*



(c) Fred Waldhauer with his Proportional Control System during *Bandoneon!*

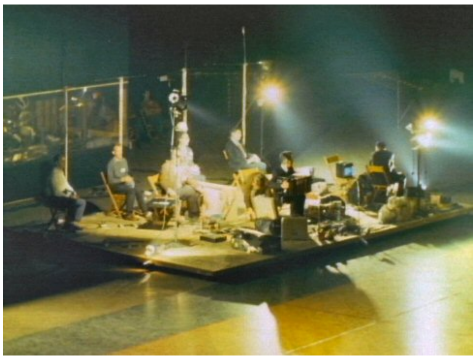
(d) David Tudor playing the bandoneon with contact mics visible

Figure 2. Various devices used in David Tudor's *Bandoneon! (a combine)*

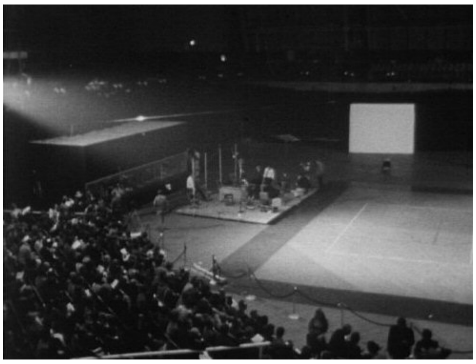
once than I ever knew I could handle. It was a mess."[38] The specific details of how each piece of equipment functioned in the piece is not crucial for creating an analysis of the underlying cybernetic and systems principles of the work. Suffice it to say that it was multimedia in every sense possible in 1966. What *is* crucial, though, is a framing of the interconnected devices as a *meta-device*. That is, it is more helpful to think of the work not as a work for bandoneon plus various technological devices, but rather as a bandoneon-apparatus, a *technological-apparatus* of which the bandoneon was the interface.

The role of Tudor is best thought of as governor, an actor within a highly unstable machine (which includes the performance building itself) and the "performance" as this governor exploring and riding this machine. It consistently wrests control from the governor, intent on creating its own destiny; hence, the reset button. Looking at it this way, the distinction between biological and non-biological systems is diminished with the bandoneon-apparatus having a will of its own. Indeed, in his review of

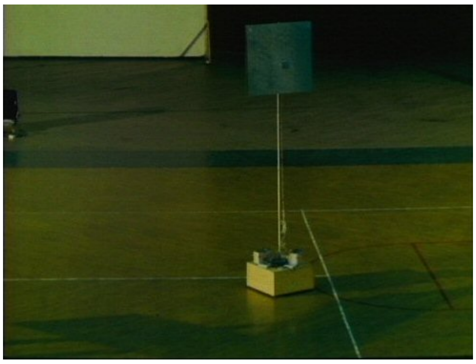
[38] Whitman and Klüver, *Notes by a Partcipant*



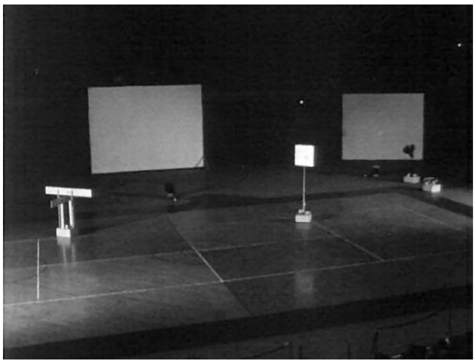
(a) On stage



(b) Performance area



(c) Mobile sculpture



(d) Two mobile sculptures

Figure 3. Images of *Bandoneon! (a combine)* at the *9 Evenings*.

the *9 Evenings*, Burnham argues that the entire production required a different set of aesthetic values to appriciate the systems as art and that "[t]his suggests that systems-oriented art... will deal less with artifacts contrived from their formal value, and increasingly with *men* enmeshed with and within purposeful responsive systems."[39] (Emphasis original) The notion of the machine possessing its own will brings to mind Wiener's anecdote about the "gremlin" in aviation: "The semi-humorous superstition of the gremlin among the aviators was probably due, as much as anything else, to the habit of dealing with a machine with a large number of build-in feedbacks which might be interpreted as friendly or hostile... [The machine] may easily be felt as a personality to be antagonized when the plane is forced into unusual maneuvers."[40]

Indeed, Broeckmann speaks of how it appears that Tudor "were working on an overly powerful interface whose complexity he could not yet master, and whose beyond-control aspects became a crucial factor of the aesthetic experience of the perfor-

[39]Burnham quotes in his review of *9 Evenings*. Bijovet, *Art as Inquiry*, pg. 33
[40]Broeckmann, *MATC*, pg. 96, note 28

mance."[41] This "beyond-control-ness" likley necessitated the particular compositional approach Tudor is said to have used in the work: "In essence, Tudors basic compositional approach in *Bandoneon! (a combine)*, one he shared with contemporaries such as Pauline Oliveros, Gordon Mumma, and especially John Cage, was to set up a series of material conditions — staging, electronic wiring, instrumental combinations, and so on — and then to conceive of a composition as a nearly automatic playing out of these conditions."[42] The question is, then, what technical and conceptual strucutres found in both cybernetics and Jack Burnham's systems aesthetics are articulated, with varying degrees of clarity, in Tudor's work?

3.1. *Technical Underpinnings*

Investigating the technical apparatus of *Bandoneon!* is perhaps the most clear and obvious resource in which to find these concepts and structures. It is itself a system — perhaps the most complex system presented at the the Armony show — which in a sense has its own life, its own desires, its own modes of being. Viewed this way, the *Bandoneon!* apparatus would be called an "open system" in the lexicon of von Bertalanffy; that is, a system which is open to responses from its environment. In this case, it is Tudor providing an input (the sound of the bandoneon) and taking the apparatus' output as feedback, makes decisions as to what to do next by stimulating the single sense organ of the apparatus: the bandoneon. The apparatus also feeds on itself: in the modulation device built by Tudor, one side of the bandoneon was modulated against the other side. Tudor: "*Bandoneon! (a combine)* uses no composing means since when activated it composes itself out of its own composite instrumental nature."[43] Surely, the instrument he refers to is the very complicated case of the bandoneon-apparatus with its various ins, outs, and what-have-yous; these are all strands Tudor must keep in his head.

In fact, the entire work and the bandoneon-apparatus itself were built on the premise of feedback: "I had discovered this principle of whats called a saturated amplifier, where you arrange feedback around an amplifier to the point where the circuit oscillates of

[41] Broeckmann, *MATC*, pg. 102
[42] Goldman, "The buttons on Pandora's Box: David Tudor and the bandoneon", pg. 54
[43] Tudor in the program notes. Morris, *9 Evenings Revisited*, pg. 17

itself. All you have to do is activate it by putting a signal in, and it can keep oscillating forever and ever. Which is one of the features of the piece."[44] This feature, incidentally, was what required the installation of the reset button on the bandoneon in order to stop the sound. Tudor again: "...by touching that button I could stop the sound. The silence was deafening, because the sound in the Armony was extraordinary. Once you started something oscillating, it would go on forver."[45] These are clear manifestations of the oscillation Wiener speaks about in *Cybernetics*. Instead of treating them as disorders, as Wiener does in his examples, Tudor treats these as properties to be harnessed and utilized for a creative end.

3.2. *Conceptual Underpinnings*

More interesting than the technical aspects of the work is the way in which *Bandoneon!* embodies (some of) the explicit conceptual aspects of both cybernetics and systems aestethics, as well as appropriating the technical features as aesthetic frameworks. For a field such as cybernetics, this is a fairly natural leap, since it does not exist within or among any particular disciplines, its concepts are readily adapted to new contexts.

3.2.1. Information

If we are to take Burnham at his word that accurate information (indeed, all the information surrounding a work) is a core feature of system aesthetics, then it must be the case that all the interactions between Tudor (the artists) and the engineers are also part of the artwork(s) and that the performance(s) during the *9 Evenings* is the "display", the physical manifestations, of these interactions, the aesthetic decisions bearing fruit. Moreover, the push-and-pull nature of the artist-engineer interactions are akin to the oscillations of feedback systems described by Wiener manifested in human-human relationships.

To paraphrase Wiener in speaking of the similarities of both man and machine: "Both of them [Tudor; the bandoneon-apparatus] have sensory receptors at one stage in their cycle of operation: that is, in both of them there exists a special apparatus

[44] Taped interview on the DVD *Bandoneon! (a combine)*

[45] Interview with Joel Chadabe in the notes for the *Bandoneon!* DVD

for collection information [Tudor: ears, eyes; bandoneon-apparatus: the bandoneon, the Proportional Control System] from the outer world at low energy levels, and for making it available in the operation of the individual or of the machine. In both cases these external messages are not taken *neat*, but through the internal transofmring powers of the apparatus, whether it be dead or alive. The information is then turned into a new form available for the further stages of performance. In both the animal and the machine this performance is made to be effective on the outer world. In both of them, their *performed* action on the outer world, and not merely their *intended* action, is reported back [fed back] to the central regulatory apparatus [Tudor, in the case of the machine; the brain, in the case of Tudor]."[46] (Emphasis original)

What of the nature of the information that is transmitted to the spectators? Is there a framework which allows the cybernetic analysis of information contained within an artwork? There are two, in fact: Max Bense's "analytical aesthetics" and a branch of artificial intelligence called *computational aesthetics*. Both purport to be able to answer these questions and provide a quantitative basis upon which artwork can be evaluated but a study on the veracity of these claims is beyond the scope of this text.[47,48] What can be said regardless of the nature of this aesthetic information, though, is that artworks — *Bandoneon!* included — are a negentropic force with regard to the system-of-things in which they exist. To be sure, an artwork is a pattern-making entity which organizes information and presents it to an audience. This is true of any and all artwork and is not limited to *Bandoneon!*.

What is further interesting about the "information" in the piece (the non-aesthetic information) is the way it is *transformed*; that is, the bandoneon emits aural information which is turned into electrical signals by the pickups. This is then routed to a numbner of devices and used as control signals. The information is thus again transformed, sometimes presenting itself in several ways simultanously. What does this say about the information's "accuracy"? Is it accurate? In what way is it accurate? What good is information if something meaningful cannot be decoded from it?

[46] Wiener, *HUHB*, 15
[47] Neumann, *Defining Computational Aesthetics*
[48] Bo et al., *Computational aesthetics and applications*

3.2.1.1. Entropy. While the work of art always appears as a negentropic force in terms of its organization, one might also point to the complexity with which *Bandoneon!* was produced and call it entropic. While true in a very superficial sense, it is also true in sense that a great deal of *Bandoneon!* is *indeterminte*; that is, indeterminacy can be equated with entropy. Not knowing how a system will respond to a message is functionally equivalent to entropy of information.

3.2.2. Cultural Contexts

To take the view of systems aesthetics, analyzing artwork only makes sense when taking into account their "assigned context."[49] This context, according to Burnham, includes not only the immediate and literal space, but also the social, political, and technological spaces within which the work exists. Taken this way, the mere fact of the collaboration as equal entities upon which the *9 Evenings* was predicated challenged the traditional role of the "artist" as we recieive it from the broader culture: that the artist is *not*, in fact, a lone mind working on an isolated island of abstraction and thoughts. This is even more the case with *Bandoneon!* and Tudor's place in it: while he certainly was the navigator or governor, the indeterminacy of the technical apparatus is striking and cannot be ignored. What is the role of a performer who is enmeshed in an instrument which they cannot fully contain nor fully control? Whom is controlling whom?

This notion also subliminally addresses an often expressed sentiment since the dawn of the Industrial Age: namely, that of man's anxiety surrounding the role of machines. As early as 1863 the novelist Samuel Butler, writing under the pseudonym Cellarius, expressed dismay at with the encroachment of machines: "Day by day, however, the machines are gaining ground upon us; day by day we are becoming more subservient to them; more men are daily bound down as slaves to tend them, more men are daily devoting the energies of their whole lives to the development of mechanical life."[50] In the paragraph following, Butler declares war against them, opines that no exceptions ought to be made, and that mankind should "go back to the primeval condition of the

[49]Burnham, *DiC, SA*
[50]Butler, *Darwin Among the Machines*, pg. 185

race." *Bandoneon!* confronts this notion head-on by assigning a machine, a man-made creation, an essentially equal role in the manifestation of an aesthetic experience.[51] Did the elevation of the machine to be equal with man in any way detract from the aesthetic experience offered by Tudor? The answer will perhaps be forever unknown as most reviewers panned the lengthy delays, "amateurism" of the event, and did not remain in attendance at the festival long enough — apart from Robert Rauchenberg's work — to see it.

Regardless, one imagines that this notion of the *uncanny*, in the sense that Stanley Cavell uses it, was awoken at some level. Cavell rejects Freud's contention that the animate/inanimate conflation does not lie behind the uncanny, but that it pricely describes it. That is, the uncanny is the "philosophical anxiety exacerbated by the ambiguity created when it is unclear whether a mind or merely an inanimate object is at hand."[52] It is interesting, though, that Cavell makes the distinction between a mind and an inanimate object for it begs the question: what is a "mind" in the first place? Since the bandoneon-apparatus pushes and pulls the work in ways Tudor cannot necessarily control nor anticipate, it does not seem out of line to say that the bandoneon-apparatus does indeed possess a kind of mind, albeit a relatively primitive one. This is consistent with the gremlins in Wieners aviators and the way Kayn speaaks of his systems as having "a sort of capacity to think for itself, a capacity which in a sense can be described as artificial intelligence..."[53] Maybe the distinction for the uncanny then ought to be not mind or inanimate object, but rather one of "our" minds (a human) and the mind of a human creation, one that seems to threaten the very essence of humanity.

[51]This is relatively commonplace in the present day with the ubiquity of interactivity in artwork, yet the fact that the fear remains is rather telling of the insecurity of man.

[52]Broekmann, *MATC*, pg. 97

[53]As quoted in *Elektroakustische Projekte* in Patteson

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