TAILSPIN : An Inquiry into the Audio-Visual Feedback Equilibrium

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ABSTRACT
This paper is an exploration and creative inquiry into the equilibrium of audio-visual feedback. Following a Research-Through Design approach, we actualized this inquiry by designing an ad-hoc audio-visual instrument: *TAILSPIN*. In this instrument, a closed audio-visual and physical loop is created between a microphone and its speaker, and a camera and its display, which are controlled by a performer. The tenets of feedback are then understood through the contextual research of cycles and loops in our natural environment. In this paper, we present the technical details of the instrument and offer novel insights into the audio-visual equilibrium within the context and intricacies of our own natural environment and organic feedback systems.

Author Keywords
Feedback, audio-visual, microphonic feedback, video feedback, equilibrium, chaos, negative, positive, controllability

CCS Concepts
• **Hardware→ Communication hardware, interfaces and storages**; Tactile and hand-based interfaces; • **General and Reference** → *experimentation*;

1. INTRODUCTION
The exploration of feedback has been an endeavor for contemporary composers since the mid-20th century and more recently, one of the topics of interest for the NIME community [1, 2, 3, 4, 5]. A feedback interface is a system that reinforces itself along the edge of *controllability*. Historically, musical use of feedback was commonly achieved using guitars or microphones. In more recent years, it also covers no-input mixing [6], spatial/physical feedback [6], digital feedback [6], and analog-digital hybrid systems [6]. The phenomenon of feedback has also been explored in visual art [7, 8, 9], however, the integration between these two domains is currently overlooked.

In the general public, there is a juxtaposition between audio feedback and visual feedback: screeching microphones may induce a wincing reaction [10] while in contrast, visual feedback can feel entrancing and hypnotizing [11]. This juxtaposition kickstarted the initial curiosity for us surrounding the topic and question of an audio-visual equilibrium.

In the context of a cycle or loop, equilibrium is a state of balance between the inputs and outputs. Feedback loops, in musical and non-musical contexts, often have an equilibrium, acting as the 'settling point', or 'steady-state'. The equilibrium allows the loop to continue circulating at a consistent rate. Within the natural environment, there are countless natural cycles in equilibrium. Some of these cycles are self-sufficient, while most are *in tandem* - i.e. loops are reliant on each other, generating a joint equilibrium.

It is the joint equilibrium between the audio and visual feedback systems that we are aiming to investigate with our DMI, *TAILSPIN*. The equilibrium in audio feedback is the ringing resonant frequency. The equilibrium of visual feedback is harder to pinpoint but can be identified as the infinite projection of a centered object. In this short paper, we initiate an investigation to see whether and how a joint equilibrium can be achieved and how it looks and sounds.

Additionally, this paper and instrument investigates the fine tunings of our natural environment, and highlights its dissonance in conjunction with humans and human interference.

2. BACKGROUND
A feedback loop is defined as a cycle where the inputs depend on the outputs and vice versa, in order to continue moving and looping [12]. In the remainder of this section, we will separately comment on audio and visual feedback.

2.1 Audio Feedback
The act of performing with audio feedback systems, generally, involves acknowledging and listening to oneself, and uncovering a resonant tone. One the earliest applications and understandings of audio feedback was through microphone usage and their proximity to speakers [10]. When a microphone hears itself, it will reamplify the signal creating a *ringing resonant frequency*: a combination of the sound system and room, rather than the audible sound of the room (Figure 1). In most situations, *microphonic feedback* is to be avoided because of the rough and sharp frequency emitted.

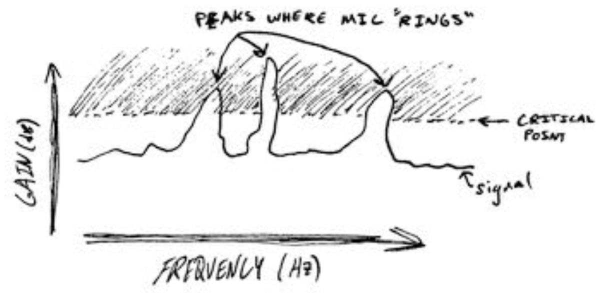

Figure 1: General visual representation to show how ringing resonant frequency "rings" after a critical point

Yet the frugalness, electroacoustic nature, and uncontrollability of the noise attracted a range of composers in the 1960s, Steve Reich and Elaine Radigue included, to explore the phenomena deeper [13,14]. The ringing resonant frequency was a tone that seemed to be born out of nothing, an unknown source, oscillating between stability and chaos [14].

Spatial audio feedback, another audio feedback system, involves creating resonant frequencies using the physical space; and its creative potential was explored in the last century by artists Albert Lucier and Pauline Oliveros. In "I'm Sitting in a Room " (1969), Lucier explored the disintegrational progression of the voice as it is iteratively recorded and played back inside the same room, slowly revealing the resonant frequencies of the room [15]. In her "Deep Listening" (1988) Pauline Oliveros' explored the natural reverberations of a two-million gallon cistern that carried acoustics for a seemingly endless amount of time [16], causing the performer to acutely listen to themselves and their own feedback.

A more recent form of creative electronic exploration of auditory feedback is no-input mixing [10], a process that uses only the inputs and outputs of an audio mixer and its internal voltage to create noise and music. Toshimaru Nokumaru, Stelios Manousakis, and Sarah Belle Reid are a few of the composers active in this niche space.

2.2 Visual Feedback

Visual feedback occurs when an object is reflected onto another reflection, creating an "infinite corridor" [11]. In the analog world, this phenomenon occurs when two mirrors are facing one another, and visualized when a centered object is placed between the two. The visual artist Yayoi Kusuma explored visual feedback in her piece "Infinity Mirror Rooms" [7], first developed in 1965, by placing objects in a cubed space where all the walls are mirrors, creating the illusion of a vast repetitive landscape when in reality, it is just a small room. In the digital world, *video feedback* is explored by projecting a camera's live video onto a screen and videoing this screen, with the same camera. This phenomenon has been explored by artists and scholars such as David Bowie, Dave Blair [8], Andrej Jay [9], Heinz-Otto Peitgen, and Douglas Hofstadner [11].

2.3 Positive/Negative Environmental Feedback Loops

Feedback loops make up our atmosphere, ecosystem, oceans and biology; one cycle leads to another, endlessly leading back to itself.

Earth is made up of loops and cycles that need to remain in equilibrium with themselves and each other in order to continue. For example, cochlea sea-shells are perfect spirals, forming from the movement of seawater within the shell and biological needs of the mollusk [17, 18]. The spiral shape of the cochlea is integral to a mollusk's life cycle as it allows the mollusk to continue growing before moving onto the next shell [18]. Together, aquatic organisms and the oceanic water cycle form a feedback system, depleting then equally replenishing each other. These cycles, in ideal conditions, are *negative feedback* loops; remaining in a constant state of equilibrium[19].

A *positive feedback* loop is a cycle that accelerates itself with time [19]. Often a negative feedback loop will transition into a positive one due to human activity. The water cycle is a system that remains in equilibrium under ideal conditions but due to the release of greenhouse gasses like carbon dioxide (CO_2), the oceans' temperature rises [20], which results in further precipitation, which then results in higher and higher sea levels [20]. Additionally, CO_2 emissions manipulates the oceans' chemistry, creating more acidic pH levels in the water, corroding and disintegrating the 'perfect' sea-shells; creating an imbalance in the mollusks' life cycle [21]. With one's feedback loop equilibrium tampered with, this then has knock-on effects via other feedback loops that are in tandem with the original loop. An imbalance like this is destructive, chaotic, and unpredictable: ultimately, shifting or removing equilibrium from the natural world.

3. TAILSPIN

We designed *TAILSPIN* to explore the precarious equilibrium of audio-visual feedback, modelled and later understood through environmental feedback loops. *TAILSPIN* was created to behave as both its own instrument, recorder, paintbrush, and canvas.

TAILSPIN is an audio-visual DMI entirely controlled by a human operator. Sound is generated through microphonic feedback and visuals are generated through video feedback (Figure 2). The pulsating red ellipse drawn on the screen is a visual representation of the microphone feedback, and the chopping of the audio is a direct response to the amount of movement from this ellipse. The hardware, i.e. the camera and microphone, is controlled by human hands and the outcome is dependent on the performance.

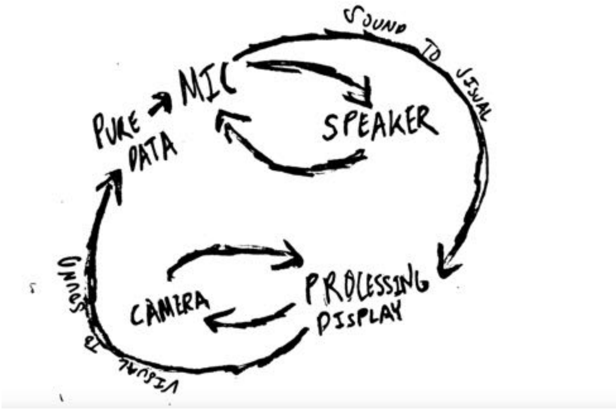

Figure 2: Overview flow chart of the entire loop, note; "speaker" means amplifier

All audio and visuals are processed with coding programs *Processing* and *Pure Data*, which handle the communication between the microphone, the camera, and the computer; additionally, the programs analyze the frequency and the amount of activated pixels that are generated.

Pure Data is used to create the microphonic feedback loop. The input of the microphone is simply sent into the audio board and outputted into the speakers with no processing. The output is then picked up again by the same microphone and re-amplified. This signal then rings out as a resonant frequency. This resonant frequency is the eventual equilibrium of the loop, making it a negative feedback loop in an environmental context. The resonant pitch is not just one pitch; it steps, with legato, between 4 different pitches. This was not an anticipated result and is something to perhaps be explored further. Our empirical observation suggests that the input gain on the microphone, the output volume, and the mic's proximity are all driving factors for creating different pitches in the resonant frequency. The textural quality of the feedback also changes depending on other electronic devices present in the room. For example, when the microphone approaches the laptop, it begins to crackle and roughen the timbre of the sound.

The microphone uses Pure Data's FIDDLE object to read the frequency values of the ringing feedback. Processing then draws a red ellipse in the center of the screen and the radius changes according to those same live frequency values. Processing is also used to project the camera's display on the laptop screen. When the camera is aimed at the laptop screen, it creates an infinite projection. The visual feedback is in equilibrium when the infinite corridor of red ellipses is present and observable (Figure 3): rendering it a negative feedback loop in an environmental context. The framerate (around 50 FPS) of the laptop (*2017 MacBook Pro on Ventura 13.0*) is not synchronized with the audio rate of the microphonic feedback, so there is visual delay with the ellipses, seen as a rippling effect or visual reverberation.

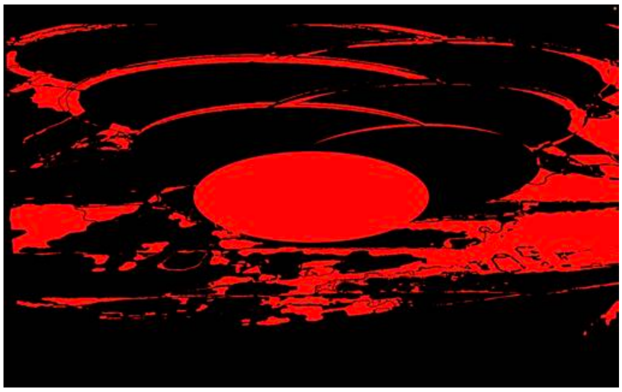

Figure 3: Screenshot of video feedback and visual reverb from *TAILSPIN* demo

Through Processing and the laptop, the camera can analyze movement. The primary movement that occurs is the changing size of the red ellipse. Activated pixels are read as *movement* and printed as data for the input gain on the microphone, completing the loop. This adds a noise gating, chopped effect to the audio feedback, additionally causing the red ellipse to undergo a blinking effect. And then this blinking effect would be picked up by the camera as further movement, continuing the loop endlessly.

The entire system is controlled by a single performer, who holds the microphone with one hand and the camera with the other hand (Figure 4). The performer uses the display and audio as joint cues for navigating the space, with an aim to understand more about the relationship and carve out where the *audio-visual equilibrium* meets. This means that the operator is an integral part of the loop, with their two hands representing the physical join of the entire circuit. Without the operator and physical exploration, a blank screen and silence would be left as residua.

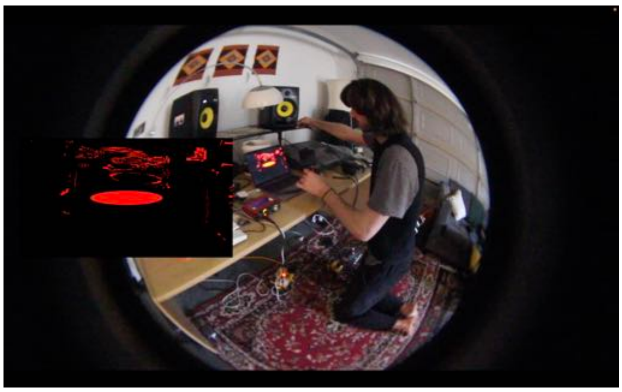

Figure 4: Operator controlling *TAILSPIN* with the right hand holding the mic and the left hand holding the camera.

4. REFLECTIONS

Through practice and experimentation, we came to reinterpret our own performance with the instrument. It became clear that *TAILSPIN* allows the performer to *play with* the equilibrium, not necessarily find it. If there is an equilibrium, it is very fragile when controlled by a human. Much like our natural environment, when we interject ourselves into natural processes, or pre-established equilibria systems, it often creates an imbalance.

There is no clear equilibrium between audio and visual, at least in the system we have created. This audio-visual feedback loop is subject to someone trying to control it; however this control sends it into a chaotic direction. The chaos in the final rendering is experienced in the hands of the operator. This leads us to believe this audio-visual feedback is a positive feedback loop in an environmental context, because of the unpredictability and potential for chaos. In a pure analogue system, we could potentially see a clear equilibrium but since this system required the use of digital technology in conjunction with analogue, the audio and visual are constantly in and out of phase with each other. The viewing of this equilibrium then becomes subject to the performer/operator noticing if and when the system is in balance.

When testing the interface, the mismatched frame rate between the camera and microphone resulted in a pulsing, visual slide-show. The ellipse feels *live* because the microphonic feedback is an *analogue* loop, while the infinite projections of the ellipse have a delayed ripple due to the laptops inability to analyze the pixels 'in time'. When the digital video feedback tries to catch the microphone's ellipse and delayed ellipses, the system is then left in a tailspin. This forces the performance to use silence, allowing the visual to catch up with itself. Even if the audio signal is not present, the camera continues to still analyze movement from the first ellipse, and then all the other successive ellipses, looping until the visual reverberation is finished: like a pond returning to flat after a stone is dropped in the middle.

Both feedback loops, microphonic and video, float along a sensitive edge, where it could descend into chaos. In our eyes and ears, audio chaos happens when the frequency is unlistenable, and visual chaos is when the image is no longer decipherable (Figure 5). When audio and visual join, this edge becomes even more narrow and the drop into chaos is much deeper. To adjust to this fine line and keep the DMI stable, the performer/operator of *TAILSPIN* must maintain an intense level of physical sensitivity; using ears, eyes, hands, and sense of space. When the audio-visual signal is constantly oscillating between a state of calm and chaos, the equilibrium in-between is rare and fractional. We can begin to infer what this equilibrium looks and sounds like by knowing the extremes and the range the audio-visual piece is oscillating between. Extending the time with this instrument is necessary to continue to identify the so-called steady state.' Additionally, enhancing this instrument to higher-powered hardware, through faster digital technology or purely analog hardware, is necessary to continue the question.

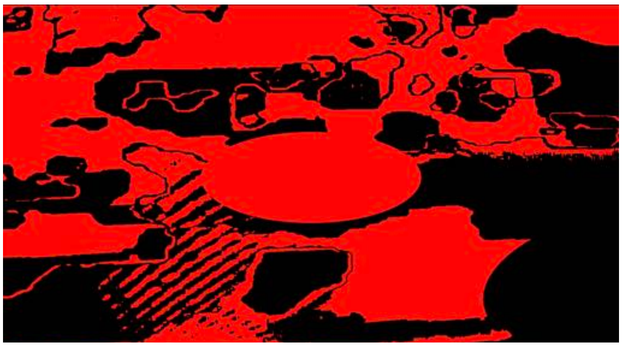

Figure 5: Screenshot from *TAILSPIN* demo, showing the 'visual chaos' when too much movement is detected, rendering unrecognizable shapes and visuals

When we examine other ideal feedback loops, particularly in the environment we can understand why an of this nature equilibrium is so fragile. There have been multiple examples in our natural environment of cycles in equilibrium that are then brought out of phase because of the implication of human involvement [19,20] In order to finitely view/hear the equilibrium, the removal of human dependency is worthy of exploration: i.e. creating a system where we can observe it objectively, with the smallest amount of our own involvement possible. This is a major effort in the fight against climate change: how can we mitigate human's imbalance against nature's balance?

5. SHORTCOMINGS AND FUTURE PLANS

5.1 Shortcomings

Since the framerate of the laptop and resultant visual feedback could never quite catch the live feedback of the microphone, the camera is left in an endless chase: Tailspinning, creating a disjointed loop. While this imperfection of *TAILSPIN* is unfortunate, it creates for an interesting juxtaposition: highlighting the ineptitude and lack of purity within digital technology, as opposed to analogue's ability to produce live feedback.

5.2 Future Plans

While the system is a loop, we began to see the circuit behave more and more as a spiral. The mismatched video framerate means loop's 'ends' do not meet: like a spiral where one end is video chaos, and the other: microphonic chaos. The artist Louise Bourgeois notes that to succumb into the spiral is an act of trust, denouncing the attempted control, the "controlled chaos" [23]. To see the equilibrium may require the releasing of human control so the natural organic outcome can take place. However, this then leads us to question the music's musicality if there is no human interaction.

Additionally, *TAILSPIN* could be adapted and played into a spiral space, like a spiral staircase, to explore the spatial/physical element of feedback. While the space is representative of the interpretation of the system and integrates spatial audio feedback, it further relates to the natural processes that involve spirals: sea-shells to human-ear cochlea as the prime example. This then connects to the perfection among certain mathematical expressions and their connection to nature: Fibonacci's sequence with hurricanes, pi with oceanic or freshwater waves, the fractals with tree branches, etc. All topics and connections would require dense research and time.

As stated earlier in the reflections' section, to achieve a more *ideal* set up, the interface would require analogue equipment and a higher powered computer where the frame-rate is able to seamlessly match the microphone without much latency (even if it is not 'live', we would be able to perceive it as live).

6. CONCLUSION

Herein, we have designed and introduced an instrument that offers a means to interact with the audio, visual, and physical space simultaneously, where the performer can play with and attempt to understand the audio-visual feedback equilibrium. *TAILSPIN*'s foundation is based on two negative feedback loops, microphonic feedback and video feedback, looped together through a laptop and a performer; creating one all-encompassing large positive feedback loop. Due to all of these dependent loops, the performer, as the independent variable, is required to be attuned to all of their available senses in order to see where the equilibrium may lie.

The feedback loops within the natural environment provided direct inspiration when designing the interface, and additionally facilitated our efforts to understand the interface post-performance. It reminded and alerted us to the chaotic implications when humans try or unconsciously try to take control of a loop, both in nature and *TAILSPIN*.

While the design, performance, and paper was driven by the question of where and what the audio-visual feedback equilibrium is, it became clear that *TAILSPIN* is a way for an operator to *play* with the equilibrium and *interpret* the equilibrium through experimentation rather than naming and pin-pointing the equilibrium.

7. ETHICAL STANDARDS

This work and enquiry is self-funded. There are no observed conflicts of interest.

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9. APPENDIX

TAILSPIN DEMO – watch/listen:
https://www.youtube.com/watch?v=VAxBCDCBdIs

PROCESSING and PURE DATA CODE – download:
https://drive.google.com/drive/folders/1RoNs5WFcwlt4IeNCSsW84FlBWVJ6jaSa?usp=sharing

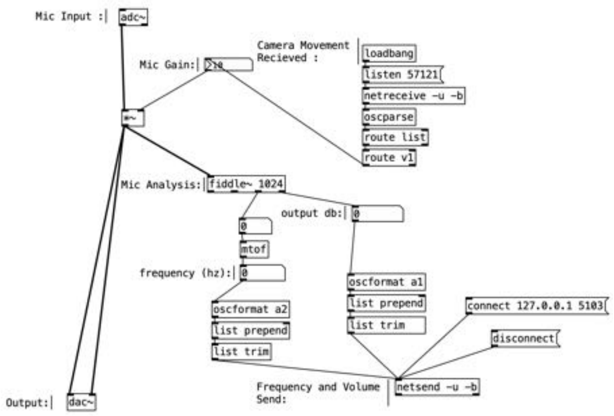

Figure 6: Screenshot of Pure Data code, encompassing microphonic feedback, and movement received from Processing