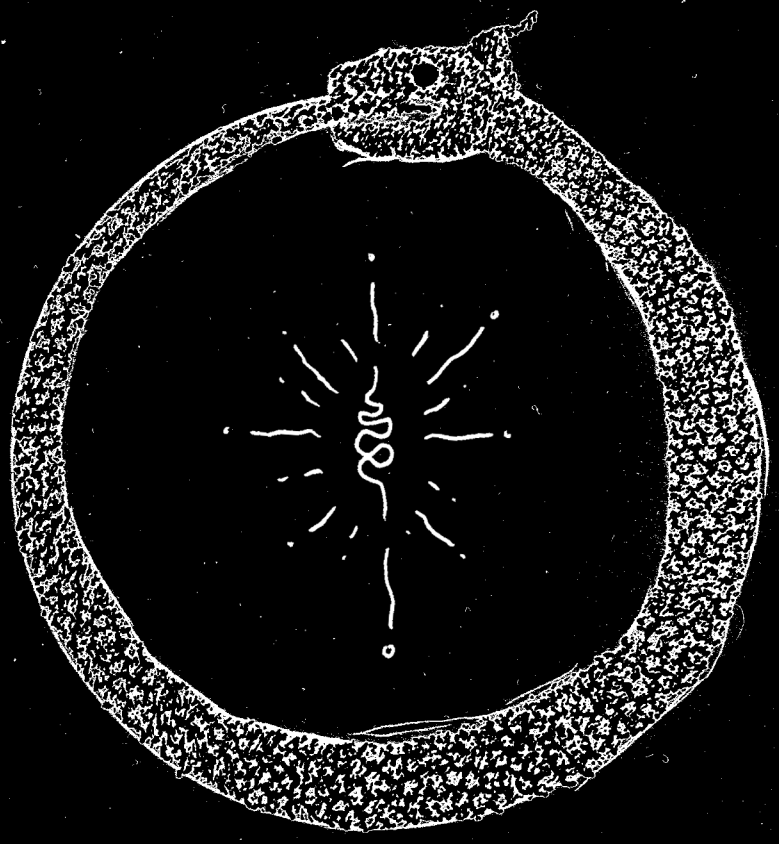

Moritz Haberkorn

The Humming of the Ouroboros

The Humming of the Ouroboros

Feedback, Self-Organization, Non-Linearity in Music & Sonic Art

Universität für künstlerische und industrielle Gestaltung
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Abstract

This thesis deals with the topic of feedback inside music and the sonic arts as means of sound production, and as a concept working with sound. Feedback is the process of routing the output of a system back into itself, as a phenomenon, it can be found inside ecosystems, social systems, mechanics, electronic circuits, acoustics, the nervous system and many more. The thesis traces a line from the science of cybernetics that first dealt with the notion of feedback in a scientific context, to its convergence with art in the 1960s, and to past and contemporary practices inside music using feedback for the production of sound. Furthermore, the notion of feedback will be applied as a model helping to understand self-emergence inside free improvised music. A scientific description of feedback and the related phenomena of chaos, non-linearity, and self-organization is given to understand the unique and fascinating behavior of feedback systems.

Dedication

To all the musicians i have improvised with in the need to break to sonic borders and limitations of the ego. Music was born free!

Acknowledgements

I want to thank my supervisors Christa Sommerer for her input helping me thinking outside my own box. I also want to thank Kevan Croton for proofreading this thesis. And my parents for supporting my studies.

Contents

Chapter 1

Introduction

"The more chaotic I am, the more complete I am." - Austin Osman Spare[1]

1.1 Motivation

As an electric guitarist, I got fascinated very early with the notion of feedback, since it is an inherent phenomenon of the practice, resulting from distortion and high amplification of the instrument. When I bought my first delay pedal (a Boss DD-6) in 2007, I got pretty fascinated with the wild sounds it would create when one would turn the feedback dial all the way up. The re-injection of the signal onto itself happening between amplifier, pick up and guitar strings became an interest of mine through the practice of playing guitar. Soon after I was introduced to experimental rock/metal bands like Sonic Youth and Sunn 0))), that used the phenomenon deliberately as a means of artistic expression inside their music. The soundscapes produced by these bands utilizing feedback where haunting and mesmerizing to me, but also seemed as something tabooed or forbidden, because of the high volume one needs to create this sounds with a guitar. Living in my house with my parents further experiments with feedback limited to a number of occasions where I was alone in the house and know I wouldn't disturb anyone. It was not until I first started to experiment with No-Input mixing that I really got obsessed with using feedback as a means of sound production and incorporating it deliberately into my own music. In No-Input mixing one is creating a feedback loop by routing back the output of the mixing board back into one of its inputs. The resulting self-oscillation inside the mixer produces

[1] () *Austin Osman Spare Quotes (Author of The Book of Pleasure (Self-Love))*. URL: `https://www.goodreads.com/author/quotes/357421.Austin_Osman_Spare` (visited on 08/20/2018).

sounds from high-squeals and bass tones to harsh chaotic noise, depending on the use of various parameters, like input pre-amplification, equalizing and signal routing. Soon I realized that I could create a broader palette of sounds by hooking up guitar effect pedals into the signal chain, introducing another layer of non-linearity and modulation to the feedback system, that offered sounds of higher complexity and a richer sonic spectrum. This led to a No-Input feedback experiment on a festival, where we tried to hook up as many effect pedals as we could get at the festival to see what kind of soundscape it would produce. The result was stunning, some sounds were akin a choir or pure tones, while others were just walls of chaotic harsh noise. But the sounds were impossible to control, it seemed like the system had it's own will and did what it wanted. So after some time we just sat back and listened to the system playing by itself. The strange thing was that the system didn't lock in a constant drone nor did it drift into complete randomness, it started to sing an ever-changing song of strange textures and tones, it felt alive, like a creature lost in the aether singing songs to find it's equilibrium; we heard the humming of the *ouroboros* [2]. The uncertain aspects of using feedback also brought me to a more improvisational and playful approach to music. After learning music theory in my former studies in Salzburg, my creative output was completely blocked with burdening rules how music should be made. Improvisation seemed to me the saving way out since it emphasizes more the immediacy and the moment itself then the outcome as a perfect whole. I started to improvise with other performers, and joined the conducted improvisation orchestra, GIS[3] Orchester. After an improvised performance of mine, I had an interesting conversation with my former teacher Dr. Michael Manfe (who was in the audience), about performance and the nature of the human self. Dr.Manfe stated: "I think when you are performing Mr. Haberkorn, you are becoming the real or pure Haberkorn, your true self. But this person would be too exhausting for you and me outside the scope of the performance."[4] This statement made me think about the nature of our personalities and things that cannot be expressed in the scope of the everyday life. It aroused my interest in how improvisation and performance can be used to explore other and darker areas of the self to complete the experience of life. So beside using feedback with No-Input mixing, playing electric guitar, and seeing how the feedback loop was also embedded inside the improvisational process, my interest arose on how feedback as a concept

[2]The snake *ouroboros* is an ancient symbol symbolizing the infinite cycle of creation and destruction, life and death. The snake eating its own tail is inside the thesis a symbol for the circular and infinite repeating trans-mutating nature of the feedback loop

[3]Go for Improvised Sounds, http://www.waschaecht.at/projekte/gis-orchestra/

[4]This quote is only an approximation of what Dr. Manfe actually said

Figure 1.1: First performance as morast @ Stadtgalerie Lehen, Salzburg 2014. (Photo: Nina Wenhart)

for artistic expression can also be applied to different fields not only concerning art but as a holistic concept: the endless devouring loop of life, begetting itself. I thought choosing it as a topic for my master thesis would offer me the chance to research into something that I use in my artistic practice in a broader context, to see what I do as an artist and experience as a human embedded in a larger context of theories, works, and artistic practices. So beside the scientific approach, this thesis is also deeply personal and features examples from artistic practices and their legacy that are related to my own work.

1.2 Artistic Background

> "Sound is my main medium since it is immaterial and physical at the same time, as well as it is time-based, creating a temporal experience that emphasizes the moment and being itself: impalpable, brittle and unreproducible." - from my artist statement

Figure 1.2: Dancers inside the installation *Epilog* at the *Tanz!* exhibition, *Deutsches Hygiene Museum Dresden.* (Photo: Deutsches Hygiene Museum Dresden)

My artistic background spans from the live performance of music and it's composition, production, and recording, as well as the creation of interactive music systems for live performances and media installations for museums and fairs. As a musician, I have performed and recorded with a diverse number of groups and people over the years, ranging from free improvisation to black metal, techno, ambient, drone, and noise-rock, mainly on guitar, bass, drums and electronics, in Austria and several other countries inside Europe. As a sound engineer, I have produced, recorded and mixed several records for bands and have produced and recorded my own music under various pseudonyms. In most of these releases, I appear under my artist name Moritz Morast or just Morast. Beside that I have worked in the scoring of films like *Ruh and Kassandra*(2015) by Aleksander Kaplun and *Fernweh/Heimweh*(2017) by Florine Mougel, which featured a live improvised score together with the musicians Daniel Stimmeder and Tanja Fuchs aka Abu Gabi.

In my work as a designer of musical electronics and programmer of interactive music systems, I have realized 2 installations for *Deutsches Hygiene Museum Dresden* together with *schnellebuntebilder*[5], commissioned for their exhibition *Tanz! Wie wir uns durch die Welt bewegen*(2014). *Tanzinstru-*

[5]http://schnellebuntebilder.de/

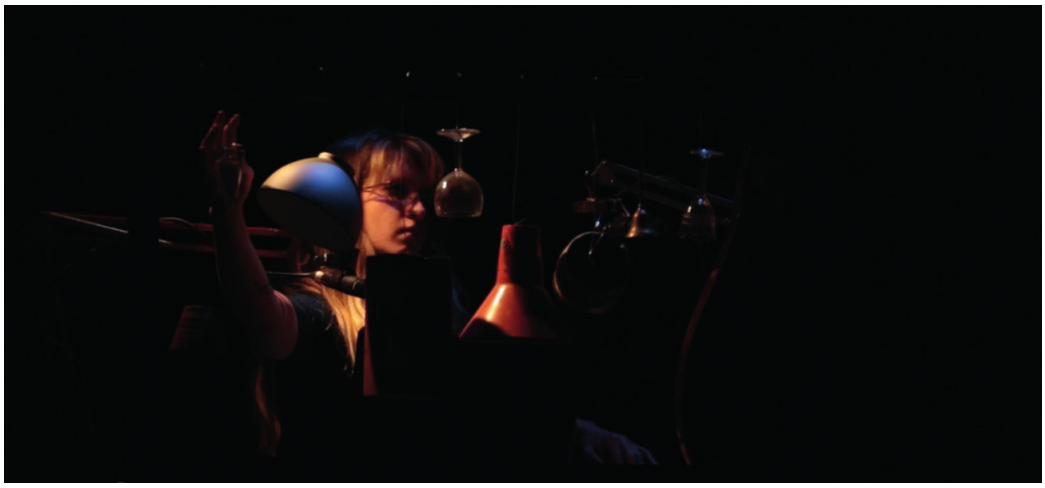


Figure 1.3: Sarah Wéry performing Omoi. (Photo: Bertrand Conard)

ment was an instrument creating music from dance moves, the other *Epilog* an immersive floor projection with an interactive soundscape (shown in 1.2). For the dance piece Omoi by Uiko Watanabe I created a live sampling software for the composer Sarah Wery that was used by her to compose the music from everyday objects in realtime (shown in 1.3).

The necessity with creating my own music systems started out of ideas for musical interactions that were not provided by available software. I first used Native Instruments *Reaktor*[6] as my main tool of creation, later switching to Miller Puckette's *Pure Data*[7] and the functional programming language *FAUST*[8]. I also built some analog musical circuits from electrical components most of them with the help of Nicolas Collins great Book *Handmade Electronic Music*. The book features simple approaches to create one's own musical circuits from cheap components that are easy to assemble and to accustom to one's needs. This made myself familiar with the art of the soldering iron and led also to some hacks of already existing musical toys and instruments. This hacked and homemade devices, as well as the software written in *Pure Data* and *Faust*, are all ingredients of my live performances and vary from performance to performance. Outside of music I like to draw and use my drawings as designs for my own and other peoples record covers and musical merchandise.

[6]https://www.native-instruments.com/en/products/komplete/synths/reaktor-6/
[7]http://puredata.info/
[8]Functional Audio Stream: http://faust.grame.fr/

1.3 Methodology

To understand how the phenomenon of feedback is used in music and the sonic arts and in my own artistic practice, the thesis first offers a historical perspective of the term and how it was conceived by Norbert Wiener and later expanded inside the science of cybernetics. Later I will describe a convergence between arts and cybernetics that happened during the 1960s, where the topics of system and feedback became an inquiry of artistic research, inside the then-new field of media art.
The second chapter describes feedback from the technical point of view to understand the features that give it it's unique behavior. We will look into the notions of non-linearity that results from circulatory processes, chaos theory, and fractals, as well as the self-organizing nature of feedback in ecosystem and organisms. I will also refer to the concept of *Autopoiesis* conceived by Francisco Varela and Humberto Maturana to describe the phenomenon of self-emergence and self-maintenance in life forms.
In the third chapter, we will look into how feedback is utilized by musician and sound artists as means of sound production, from rock music to electronic music pioneers and contemporary avant-garde musicians. Furthermore, we will apply our findings of the second chapter on how feedback and self-organization can be used as a model for free improvised music, and why music made with feedback suggest an improvisational approach to music making.
The final chapter will relate my own artistic work inside the practices, theories, and approaches described in the previous chapters. The aim of the thesis is not to use the scientific approaches of cybernetics to analyze the artistic practices described. Instead, these ideas and models serve us as an inspiration to challenge new ways of thinking and approaches to describe the work of artists utilizing feedback inside sound, music, and improvisation. Like Roy Ascott (2002, p. 4) said: "we are referring to the spirit of Cybernetics which may inform art and in turn be enriched by it.".

Chapter 2

Into the feedback loop

2.1 Beginnings of Research

What we call feedback is the process of routing the output of a system back into itself. Through this connection of the output to the input one is establishing what we call a feedback loop. This feedback mechanism can be found in a wide range of different systems: ecosystems, social systems, mechanics, electronic circuits, acoustics, the nervous system and many more. Probably the first documented deliberate use of feedback by humans was inside mechanical regulatory mechanisms for machines. The centrifugal governor (shown in 2.1) designed by James Watt, would open a valve inside a steam machine when rotating at a certain speed by centrifugal forces, that would cause the opening of the valve to lower the pressure and speed of the steam engine, allowing for automatic regulation of the systems. In 1868 Clerk Maxwell published the first scientific essay on the use of centrifugal forces as regulation mechanisms

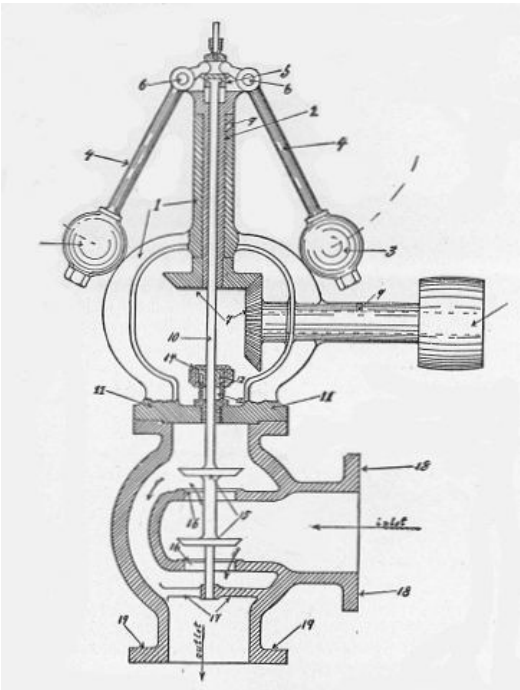


Figure 2.1: Diagram of an centrifugal govenor. (Source:https://en.wikipedia.org/)

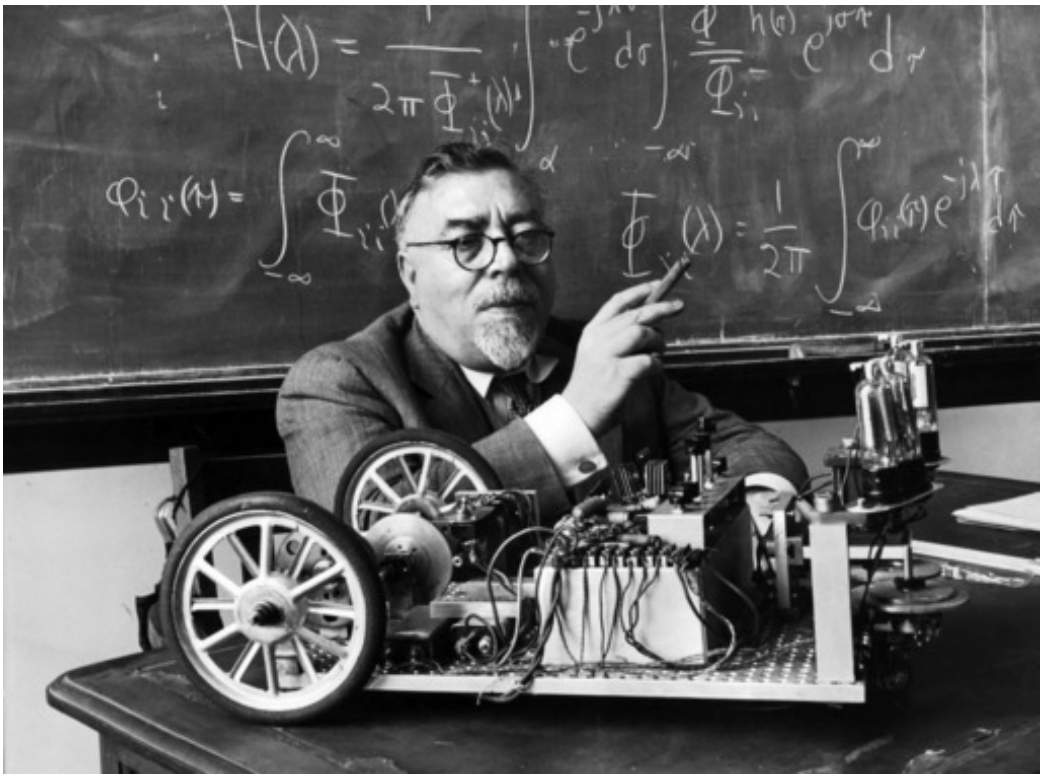


Figure 2.2: Norbert Wiener. (Source:https://imgur.com/)

for steam machines, though Watt's Centrifugal Governor was invented nearly a century before (Wiener 1963, p. 39). This essay marks the beginning of the research on feedback as a mechanism that allows for self-regulation and control for machines, that would become even more important in the next century, leading to the research of Norbert Wiener and establishment of the science of Cybernetics that deals with the concept of feedback as a method for self-control.

2.2 Norbert Wiener & Cybernetics

The mathematician Norbert Wiener was the first who took the concept of feedback outside of the context of engineering, applying it to all problems that require some sort of self-controlling mechanisms. As Warren McCulloch (2003, p. 719), chairman of the Cybernetic Conferences said:

> "Our meetings began chiefly because Norbert Wiener and his friends in mathematics, communication engineering, and physiology, had shown the applicability of the notions of inverse feedback

> to all problems of regulation, homeostasis, and goal-directed activity from steam engines to human societies."

Wiener had already been dealing with the notion of self-regulating mechanisms in his work on automatically aiming anti-aircraft defense weapons for the USA during the 2nd World War, that could anticipate the flight trajectory of an aircraft. With his partner Arturo Rosenblueth he applied the concept of feedback from the world of engineering to the nervous system of living organisms, describing it as a circular system where there is a constant exchange of information between muscles, brain and sense organs, instead of a one-directional concept where orders are being sent from the brain and carried out by the muscles. Through the use of this concept Wiener and Rosenblueth were able to describe the causes of Ataxia; a disease that is a defect inside the nervous system that causes people to quake and oscillate when trying to grab an object (Wiener 1963, p. 145). Their work resulted in the essay *Behavior, Purpose and Teleology*(1943) together with Julian Bigelow, that sketches a theory on how to model purposeful behavior that strives for achieving a certain goal or cause. The essay proposes a shift from the functional analysis of the intrinsic structure of an object, to a behavioristic approach that studies the relationship between input and output of an object and where its behavior is defined as "any change of an entity with respect to its surroundings" (Rosenblueth, Wiener, and Bigelow 1943, p. 18). The input/output relation that constitutes the feedback loop has a corrective function, that guides the behaving object towards a goal. In the essay, this is called teleological behavior, where actions are based on their purpose and not a specific procedures.

> "[P]urposeful reactions [which] are controlled by the error of the reaction — i.e., by the difference between the state of the behaving object at any time and the final state interpreted as the purpose. Teleological behavior thus becomes synonymous with behavior controlled by negative feedback, and gains therefore in precision by a sufficiently restricted connotation"(ibid., p. 24)

Wiener believed in an uniform behavioristic analysis of machines and living organisms, which he formulated into a holistic theory in his book *Cybernetics: Or Control and Communication in the Animal and the Machine* in 1948, that describes how self-control and regulation are realized through feedback in the said systems. This new theory of cybernetics should be offering a method for regulating the flow of information through feedback loops between various interrelated components in order to predict and control the behavior of the system as a whole (Shanken 2002, p. 2).

Figure 2.3: Participants of the 10th Macy Conference, 1953. (Source: Claus Pias: Cybernetics. The Macy Conferences 1946-1953)

2.3 The Cybernetics Conferences

The Macy or Cybernetics Conferences were a series of meetings that were held between 1946-1953 at the *Josiah Macy, Jr Foundation* in New York. Originally called *Circular Causal, and Feedback Mechanisms in Biological and Social Systems* the conference was renamed to *Cybernetics*, as a reference to Wiener's book. The goal of the conference was to work out a new theory that should unite recent advances from the field of information theory, with developments in neurophysiology, as well as approaches from psychiatry, anthropology and sociology (Pias 2004, p. 10). Due to this interdisciplinary approach, the conference featured scientists and researchers from different backgrounds, with Warren McCulloch as the chairman and scientific advisor of the conference. What unified these different scientists was the sharing of a set of models and a certain scientific approach that was majorly influenced by three publications that were written in the early 1940s: Norbert Wiener's theory of behavior as a non-deterministic but still teleological feedback loop, which he created together with Arturo Rosenblueth and Julian Bigelow[1], the work of Pitts/McCulloch and their theory of a logic calculus of nervous activity as a stochastic theory of the symbolic[2] and Shannon's information theory as a universal theory of digital machines[3]. These theories were a foundation

[1] *Behavior, Purpose and Teleology*(1943)
[2] *A Logical Calculus Immanent in the Ideas of Nervous Activity*(1943)
[3] *A Mathematical Theory of Communication*(1948)

for the discussion of the conferences and served as a medium of communication between the researches. The topics discussed were rather broad and reached from linguistics, to homeostasis in ecosystems and living organisms, the first discussions on how artificial intelligence could work, and how machines could learn. The notion of the feedback loop was applied to all kinds of scenarios where the achievement of a goal was involved, which soon led to the use of the concept in a pervasive way; the cyberneticians started to apply their models from cases like the piloting of moon-rockets, to human breathing, cellular biology, and cooking procedures, in a sometimes more, sometimes less successful way. More and more the theorists saw themselves immersed in a gigantic feedback loop to a near cosmic extent: family, society, culture, environment and the universe (Von Foerster 1993, p. 63).
The use of the concept of the feedback loop marks a shift from the simple notion of cause and effects chains, where causes stay unaffected from the effects they produce, to the circular approaches of cybernetics where causes are also effects and vice versa. This challenges a networked thinking, where everything appears as a huge interconnected system that is influencing each other. This system based thinking became crucial to the science of cybernetics and it's offspring system theory. The holistic demand of the cyberneticians onto their new theory makes cybernetics a science of models, that is more interested in unifying analogies than classifying and separating elements from each other (Pias 2004, p. 24). What became important was to see the circularity in which everything was embedded, and to see the connections between its elements, which makes cybernetics in contrast to other sciences an integrating instead of separating one.[4]

2.4 Art & Cybernetics: Convergence in the 1960s

During the 1960s the cybernetic topics of systems, information, feedback, control, and circulatory processes became the inquiry of artistic research and expression for artists from different fields and backgrounds. The roots of this interest can be found inside avant-garde-art-movements like Dadaism, Fluxus, concept and performance art which incorporated art-pieces that were based on variations of formal instructions, audience participation, concepts, happenings and events (Paul 2007, p. 27). Within these movements, the focus of art already shifted away from the art piece as an essential unified object, towards the exploration of the dynamics of the exchange of informa-

[4] *Das Netz* 2005, 01:09:23.

tion between artist, audience and the art piece itself, inside a self-developing system, and it's underlying feedback loop (Fischer-Lichte 2004, p. 61).
But it was not until the British artist Roy Ascott published his article *Behaviourist Art and the Cybernetic Vision* in 1966, that these tendencies inside art were connected with the ideas and models of the cybernetic theory in a direct sense. The article describes this shift from the deterministic and essential vision of past classical art and it's perfect/divine object to the process-based, open, uncertain, participatory and indeterministic approaches of these avant-garde movements (Ascott 2002, p. 1), (Paul 2007, p. 27). For Ascott the cybernetic theory, forged in the Macy Conferences, offered him and other artists a scientific model for their artworks that were focusing on systems of visuals signs and their relationships, that would function as an information system (Shanken 2002, p. 1). Ascott declared the objectives of art to be the processes of artistic creation and reception, and redefined art as cybernetic systems comprised of networks of feedback loops, where creativity is not only left to the artists alone but by the creative behavior the work induces in the spectator and the society.
The American art historian Jack Burnham talks about a shift to *systems-esthetics* that is the underlying theme of these new artworks. The reason for this change lies for Burnham in a transition from a industrial to an information society from an object-oriented culture to an system-oriented culture, where information is the key to power instead of material wealth and where "change emanates not from things but from the way things are done."(Burnham 1968, p. 31). Also, the rise of technocracy and the way technological system determine more and more political and economic decision, that becomes more evident in the 60s, can be seen as a reason for artists to deal with the notion of systems. Exhibitions like the *Cybernetic Serendipity* at the *Institute for Contemporary Arts London* in 1968, gathered artists whose works were focusing on this new form of cybernetic art, bringing together artworks from diverse fields that all were connected through the use and exploration of the cybernetic principles of systems, information, feedback, and circulatory processes.
Also, the visual effects of feedback became a focus of artistic research in the 60s, when video equipment became available at a more affordable price on the consumer market. This allowed for experimentation with electronic circuits and it's visual effects outside the lab. The feedback of video cameras pointing at their own screen, filming itself, became a method of creating mesmerizing abstract images not seen before, that influenced the visual language of the psychedelic generation and American counterculture of the 1960s. By tilting the camera in front of the screen and experimenting with controls like zoom, brightness, and contrast, artists were able to explore the worlds of infinite

Figure 2.4: Skip Sweeney working on video feedback. (Source: http://www.kunstkritikk.dk)

repeating abstract images with very little equipment. Video feedback was known to be of a mysterious nature and very difficult to control, due to the many variables inside of the image (Johanna Branson Gill 1992, p. 79). One of the early masters of video feedback was the artist Skip Sweeney, organizer of the first video festivals and founder of the video artist groups *Video Free America* and *Electric Eye*. Sweeney was getting involved in the bay area video scene in the mid-1960s and started to produce videotapes featuring his works created with video feedback inside his basement in the late 1960s (Peter Weibl et al. 1992, p. 148). Sweeney's approach to video feedback was of a tinkerer's nature, playing around with different camera settings and monitors to achieve his results. He understood video feedback as an instrument which could be interacted with in real-time, for example in the form of live performance, that requires patient and obedience from the artist to unveil its organic beauty.

The cybernetic approach in the arts that made the term and use of the phenomenon of feedback and other cybernetic ideas more popular, cannot be seen as a direct permutation of the cybernetic theory into the arts. Roy Ascott was rather referring to the spirit of cybernetics and its idea of unifying elements through the use of analogies, than trying to push scientific facts into art pieces (Ascott 2002, p. 4).

Another characteristic of modern art is also its diversity that implies also

a form of unity. An idea that seems also characteristic for the 1960s, the dream of an interconnected peaceful unity of all things inside the universe envisioned by the psychedelic generation inside America's counterculture. As Roy Accott says: "There is reason to suppose that a unity of art, science and human values is possible; there is no doubt that it is desirable. More specifically we propose that an essentially cybernetic vision could unify and feed such culture." The 1960s can also be seen as a period where cybernetic theory was finding its way outside experimental scientific expert discussion into the public discourse and was therefore provoking new views onto the world (Feustel 2015, p. 10). Today these models have been taken over into our ordinary knowledge and are used in a pervasive way, the concept of the feedback loop is a commonly known phenomenon and also found it's way into our common use of language, referring to return information back to the speaker[5]. Since the cybernetic ideas have found a way into our daily lives their technical background seems somehow forgotten since the concept is taken for granted nowadays (Gere 2007, p. 63).

[5]"Give me some feedback!"

Chapter 3

Feedback Properties

Feedback is an alteration of input by output, where input is any external event that modifies the object in some manner, and output change produced in the surroundings by the object (Rosenblueth, Wiener, and Bigelow 1943, p. 1). By definition, a feedback loop consists of an output that routes back into the input of the same system. That means one operation that is done by the system is influencing the next and every operation is informed by a former operation. This implies some sort of history or evolutionary process inside the feedback loop since every operation is based on the accumulation of the past ones. This makes the system sensitive to its initial conditions that influence the further evolution of the system. Every feedback system is depended on an initial impulse that engages the process and determines it's further development. Feedback is a complex matter that exhibits a very unique behavior which results from its circularity and non-linearity. This and the phenomenon of self-organization, chaos and fractal dimension that result from its circularity shall be described in the next section.

3.1 Circularity, Non-Linearity, and Recursion

Through the connection of input to output, a system using feedback becomes circular. Circularity is a concept opposed to the simple, one-dimensional notions of cause-and-effect chains, where the cause stays unaffected from the effects it produces. In circular systems effects are also causes that retroact on themselves, breaking the linear input-output proportion. This behavior assumes a mutual relationship between the effects and their causes which leads to the non-linear behavior of the circulatory system. Whenever parts of a system interfere, or cooperate or compete there is a non-linear interaction going on (S. H. Strogatz 1994, p. 9).

Non-Linearity is defined as a behavior where there is no proportional relationship between the causes and effects of a system. In a non-linear system, smaller causes can have bigger effects, than big causes, that means that even simple non-linear structures can exhibit complex and surprising behaviors (S. Strogatz and Kober 2004, p. 258), (Sanfilippo and Valle 2012, p. 32). Most natural phenomenon and systems are of a non-linear behavior; linear behavior being the exception that represents an idealized situation where a system is near equilibrium and is not disturbed by outside influences, which is rarely the case when an isolated environment is not provided.
Another feature that stems from the circulatory organization of feedback loops is that they allow for recursive processes. Recursion is a nesting procedure, that can operate on the results it has begotten using the same operation. Recursion is based on the principle that the same operation is happening on different levels of the feedback-loop, but the results of the operation will be different on each level since it operates on the results of the former iterations (Hofstadter 2008a, p. 161). In recursive processes, there is no explicit definition of the results but the definition of a basic set of rules of operation, that will have different results depending on the initial input of the recursive procedure. In a set generated by recursion, every element is defined through the accumulation of all preceding elements which implies a kinship between the elements of the set. Hofstadter (ibid., p. 164) claims that a complex enough recursive system can break out of any foreseeable pattern.
Recursion is commonly used in mathematics and computer science to create sequences that are based on a chronological order or history to model natural phenomena like crystalline structures or population growth. Recursion is a very interesting method since it can create new forms from the same set of rules just by changing the initial starting conditions. Recursion enables the creation of variations based on the same theme, which makes it interesting for the production of series in art. Many generative art pieces using computers are based on recursive processes that enable the creation of a series of variations based on a set of basic instructions. Examples of this can be found inside the works of Vera Molnar(shown in 3.1), Frieder Nake or Casey Reas. One should note that recursiveness does not imply non-linearity itself, the non-linear behavior must already be defined inside the rules of the recursion to exhibit non-linear behavior. Feedback loops are recursive structures with a non-linear behavior.

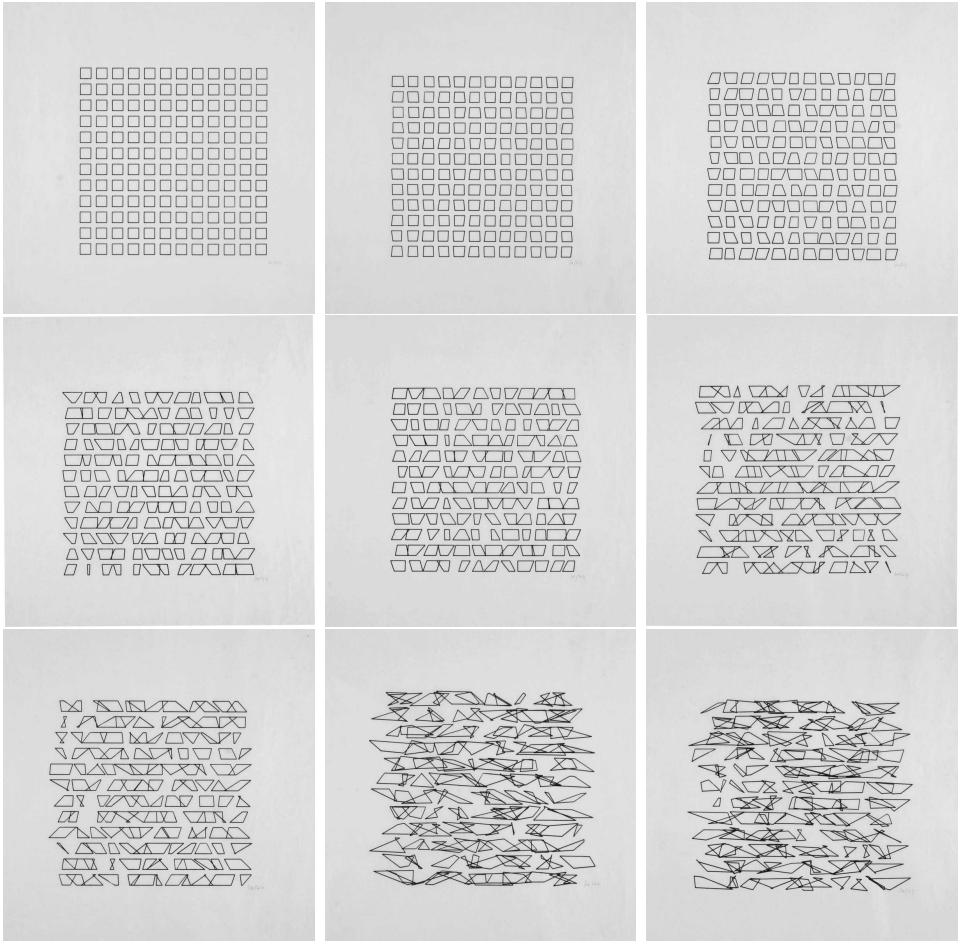


Figure 3.1: Vera Molnar's 144 Trapeziums show the distorting effect of the recursion inside a positive feedback loop. (Source: https://digitalartmuseum.org/)

3.2 Positive, Negative and Bipolar Feedback Loops

In all feedback systems, the input-output relation of the system is defined by the gain that sets the ratio of the amount of output flowing back into the input (McCulloch 2003, p. 720). Positive feedback is present when the part of the signal from the output that reenters through the input has the same sign as the original input signal. Negative Feedback is the opposite, the reentering signal having a different sign than the original input signal.
In a positive feedback loop, the output to input relation is direct, meaning an increase in output will have an increase in input. Negative Feedback has the inverse behavior; increasing the output will result in a decrease in input. This makes negative feedback suitable for all types of systems of regulation and compensation since negative feedback returns the system to the desired state by subtracting the input from an amount that increases with the deviation from that state; a negative feedback loop will tend to establish an equilibrium around a desired range or value (Sanfilippo and Valle 2012, p. 30). In contrast, positive feedback loops tend to exponential growth (Hofstadter 2008b, p. 89); with every iteration of the feedback loop, the output will increase, that makes solely positive feedback systems unstable since small perturbations can grow into huge deviations from the original conditions of the feedback loop fast (Sanfilippo and Valle 2012, p. 30).
In most cases, a feedback system not only consists of one positive or negative feedback loop but several ones that can show either positive or negative behavior; this hybrid-system is called a bipolar system. The combination of negative and positive feedback ensures the stability of the system through the use of negative feedback, while utilizing the amplifying effect of a positive feedback loop.
One should also notice that the transmission of signals, as it happens inside feedback loops, is time and frequency dependent, which causes a system to be positive for certain frequencies while it may be negative for others (McCulloch 2003, p. 720), (Rosenblueth, Wiener, and Bigelow 1943, p. 2).

3.2.1 Oscillation

In some cases as a result of a defect inside the corrective feedback (a lack of negative feedback or lag in arrival) a system can start to oscillate. If the feedback lags behind in correction, the steering mechanism will overshoot then try to correct into the other direction which will overshoot again. In an uncontrolled case the system merges into an wild oscillation that can lead

Figure 3.2: Selforganizing behavior inside a swarm of birds. (Source: D. Dibenski - images.fws.gov ([1]), Public Domain, https://commons.wikimedia.org/w/index.php?curid=3440966)

the mechanisms to break down (Wiener 1963, p. 33). Oscillation can also be a desired effect, that is deliberately used inside oscillating circuits for synthesizers, clock signals or radio broadcast.

3.3 Self-Organizing Principles of Homeostasis and Feedback

Self-organization is a dynamic process inside a system, over which course the system is ordering itself and realizes it's own structure [1]. This process happens autonomously, meaning the system is realizing its structure, through local interactions between its components, without the involvement of an external entity. The process of self-organization happens decentralized and distributed, without any main operator that guides the process,

[1]Here we are referring to organization or order as relations between elements that constitute the appearance of parts as a unit of a certain class, and structure being the elements and relations that constitute this organization (Maturana and Varela 1987, p. 54).

the system is controlling and regulating itself, based on the simultaneous interaction between its constitutive parts (Sanfilippo and Valle 2012, p. 32). Self-organization emerges from the non-linearity and recursive nature of the feedback loop. Positive feedback is amplifying noise and random fluctuations inside the system, creating structure, while negative feedback is stabilizing and regulating the system and slows down its over-activity (Kinnebrock, Werner 2002, p. 176), (Von Foerster 1960, p. 11). Through these mechanisms, coherent patterns can emerge spontaneously from within the system itself.

Feedback returns information about the current state back to the system, that means feedback allows for some sort of self-observation that enables self-regulation and self-maintenance of the system. As mentioned a negative feedback loop will tend to bring the system towards an equilibrium or stable state. The self-organizing system is performing a selection of a set of values for which the system is stable and rejects values that destabilize the system (Ashby 1991, p. 118). This process of keeping the equilibrium of a system is known as the homeostatic process. The homeostatic state takes care of holding the equilibrium as well as to return to it after a perturbation. The homeostatic process guarantees for stability and adaption, when changes outside the system, or inside it, throw it outside its balance. If the equilibrium of a system is disturbed the system will start to oscillate and try to come back into the proper range of the homeostatic state (Ashby 2003, p. 598).

If the feedback lacks in correction through negative feedback it can cause the oscillation to grow stronger until it causes the system to break down (Wiener 1963, p. 33). For a simple system like a pendulum this equilibrium can be a single value but for more complex systems the state of equilibrium is not a fixed state but more a range of values that provide for a consistence functioning of the system. This dynamic equilibrium of a complex system is a trajectory on which the system moves through different states of stability. That said, a perfect equilibrium is never reached by the system and the homeostatic process continues until the system ceases to exist. The homeostatic is the essence of all self-regulating systems.

For Ashby (1991, p. 111) a good self-organizing process builds an organization that ensures the functioning of the homeostatic process, by making the system stable around an assigned equilibrium. Self-organization and homeostasis take place in biological and social systems, and has been applied through cybernetics to problems of engineering where self-regulation is required. All forms of recalibrating mechanisms found in machines, where the output is constantly compared with the input, are man-made emulations of the homeostatic process (Heinz, Mead, and Teuber 2003, p. 534). That said, self-organization and homeostasis happen in all feedback based systems.

The biologists Humberto Maturana and Francisco Varela used a similar concept called *autopoiesis* that describes the phenomenon of self-reproduction and self-maintenance in life forms. A system is autopoietically organized when it is capable of realizing and maintaining a network of processes that can reproduce itself (Maturana and Varela 1987, pp. 71-72). The interaction between the processes and parts define the system as a unit since these processes are building together their inherent structure, that is greater than the sum of its parts. For Varela and Maturana life forms are defined through their autopoietic organization, but the use of the term has expanded to describe other sorts of reproduction and self-emergence when considering improvisation in performance art (Fischer-Lichte 2004) and jazz (Walton, Richardson, and Chemero 2014).

3.4 Chaos

Chaos refers to the notion that a system based on non-random, deterministic laws, can exhibit quasi-random and unpredictable behavior (S. Strogatz and Kober 2004, p. 254). The origin of the chaos theory was the discovery that even the smallest perturbations inside a system can grow fast exponentially, and can have a suddenly huge effect on the whole system (Von Foerster 1993, p. 148). This so-called *butterfly effect* was discovered by Edward Lorenz whilst researching simplified models for convection rolls for weather forecasts. Lorenz realized that the solutions for his equations never settled down to an equilibrium or to a periodic sequence, but continued in an irregular aperiodic oscillation. Also, he realized that slightly different initial values would result in a totally different behavior of the system after time (S. H. Strogatz 1994, p. 3).

In a mathematical sense, chaotic systems consist of differential equations for which an analytic solution cannot be found. This is either due to too many degrees of freedom, or too many relevant aspects that cannot be measured inside the equation. Normally these equations are tackled by simplifying the differential equation that can then be solved numerically, but this again introduces tiny inaccuracies, that can have a huge effect on the final result (Kinnebrock, Werner 2002, pp. 115-116), (Mackenzie 1994, p. 36).

It is common for nonlinear systems to display both regular and chaotic behavior for different parameter values (ibid., p. 44). According to mathematician Mitchell Feigenbaum these points of transitions, appear in different systems in the same way, meaning that different systems can go chaotic in the same manner (S. H. Strogatz 1994, pp. 3-4). This universal constant of transitions is called Feigenbaum constant. Feedback systems through their non-linearity,

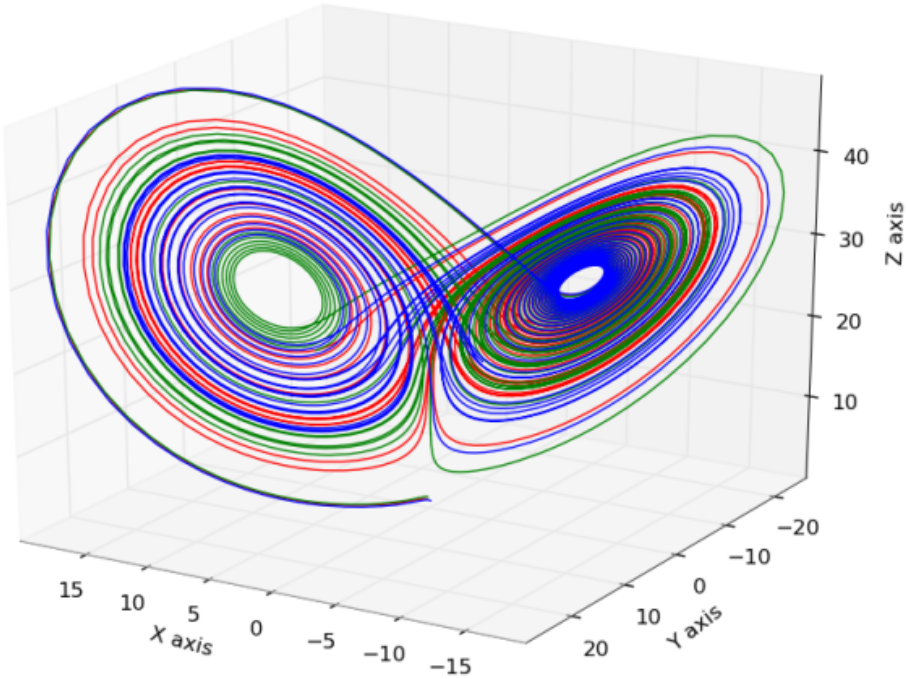


Figure 3.3: Rendering of the Lorenz attractor. (Source: https://titanlab.org/)

can also exhibit chaotic behavior after passing the points of transition of the Feigenbaum constants; chaos is an inherent feature of the feedback loop.
In a feedback based system, where parameters and values are closely interconnected, chaotic behavior is more likely to occur than in a simpler system with fewer variables or ones that are less closely linked to each other. The more parts of a system are closely interconnected, the more non-linear behavior is introduced to the system (Dahlstedt 2004, p. 74), (Ashby 2003, p. 601).

3.4.1 Attractors

One might think of chaos as total noise or randomness, shapeless because of it's unpredictability, but Lorenz proved that there were structure and rules that governed his chaotic equations. When he plotted the solution of his equation into 3 dimensions he found a butterfly-like shape that is today known as the Lorenz attractor (shown in 3.3) (S. H. Strogatz 1994, p. 3). An

attractor is a trajectory that describes a set of values a dynamical system [2] is gravitating towards after different initial starting conditions. Attractors describe the long-term behavior to which a system settles after transients (Mackenzie 1994, p. 39).
Roughly there are 3 types of attractors. The fixed point attractor is the simplest form where the system moves towards a single state, like the equilibrium a pendulum rests in after dissipating all its energy. Then there is the limit cycle attractor where the system moves through a sequence of states periodically (Crutchfield 1992, p. 195). In case of a chaotic dynamic system, the attractor is called a strange attractor that moves in an aperiodic and unpredictable fashion. This attractor describes the form of chaos, though chaos is aperiodic and does not repeat itself in its details, the values of a chaotic systems will never leave the trajectory of the attractor, that means the attractor is globally stable, while locally instable. Chaos means that the trajectory that shapes the attractor is never ending, but will always move through the same subset of states on the attractor. This constrain constitutes the order of chaos, an entity that doesn't change, the same states but never in the same sequence (S. Strogatz and Kober 2004, p. 269). In feedback systems there are normally one or many attractors inside the state space[3] the system can settle on (Crutchfield 1992, p. 194). Crutchfield (ibid., p. 201) who was researching into the behavior of video feedback systems states:

> "An attractor is globally stable in the sense that the system will return if perturbed off the attractor. Different initial conditions, even states very near each other, can end up on different attractors. The set of points, though, that go to a given attractor are in its basin of attraction. The picture for a particular dynamical system is that its state space is partitioned into one or many basins of attraction, perhaps intimately intertwined, each with it's own attractor. [...] Thus while globally stable, the entire image cannot be described by a single attractor."

A feedback system can go to different attractors inside of the state space it inhabits, depending on it's initial starting positions. It is also possible to perturb the system too much resulting in that one will knock it to another basin of attraction, in the state space. Furthermore, the attractor can be deformed with the changes of parameters of the system, this is called bifurcation.

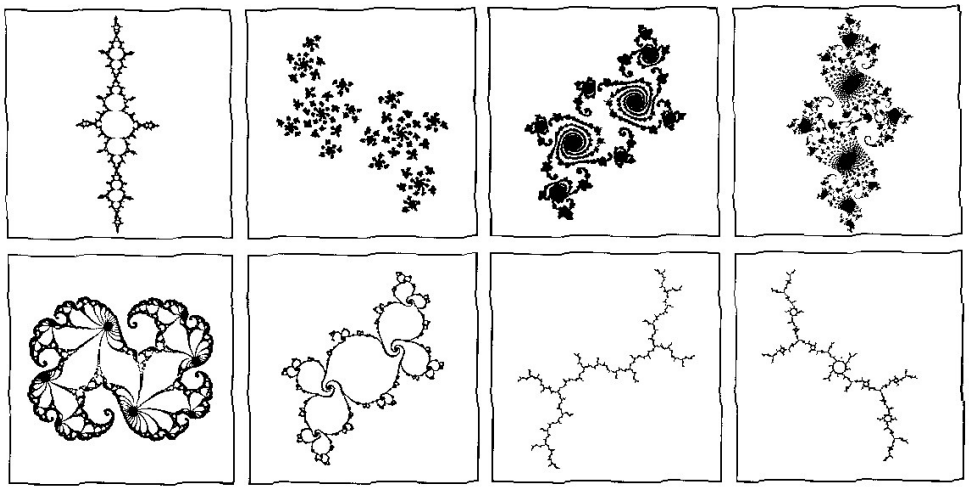


Figure 3.4: Images generated from the Julia set. (Source: http://www.sfu.ca)

3.4.2 Fractals

Fractal images are a good example of how the described chaotic behavior can be used to create stunning structures that resemble natural objects or complex abstract forms. The strange attractor of a chaotic dynamic system is basically a fractal since the attractor posses the same typical features that are characteristic for fractals: self-similarity and fractal non-euclidean dimension (Kinnebrock, Werner 2002, p. 153), (Mackenzie 1994, p. 40).
Self-similar structures are structures where the shape of the smaller parts is resembling the shape of the larger parts (Loy 2011, p. 351). In a fractal dimension, the position of a point on a curve cannot be described as a one-dimensional offset from another point, how it is being done in Euclidean geometry. Inside a fractal, the distance between two points is infinite, even if the area bounded by the curve stays finite. This infinity explains the endless richness of forms that can be found inside of fractals. The most famous examples of fractals are probably the Julia (shown in 3.4) and Mandelbrot set (shown in 3.5), the latter being based on a refined version of the first. Both are based on a recursive feedback process of transformations on the Gaussian complex number plane, and create mesmerizing visual structures.

[2]Time discrete systems
[3]All possible states the system can inhabit

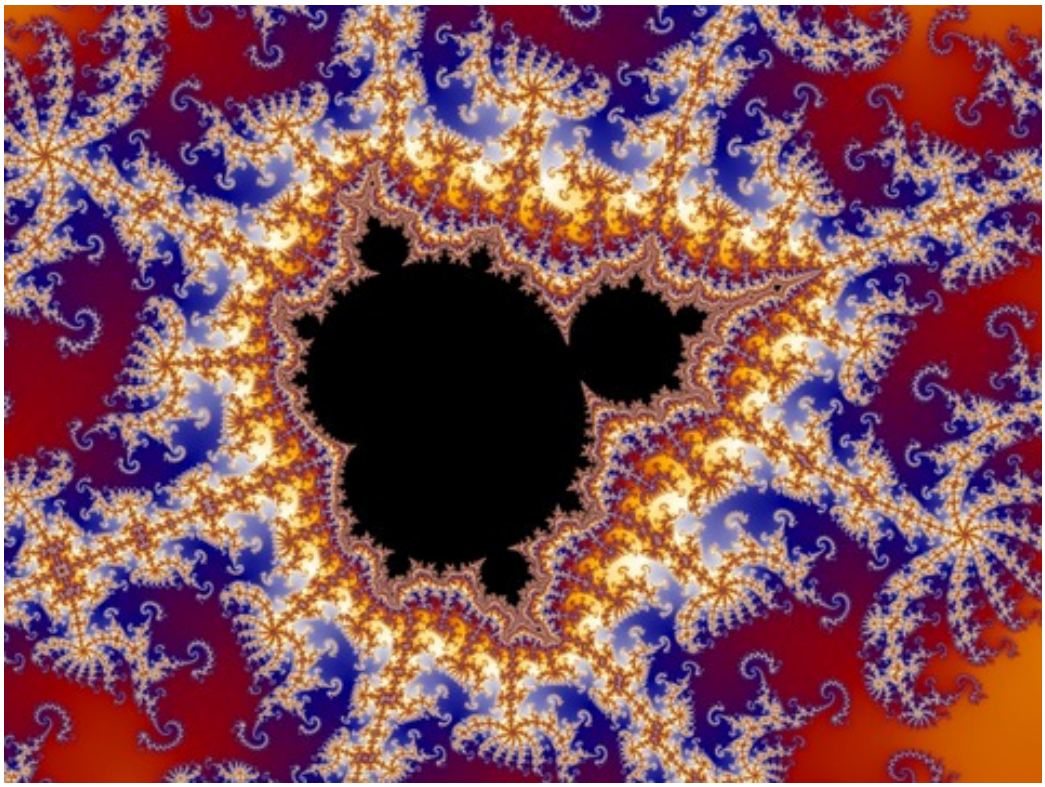


Figure 3.5: Mandelbrot Set. (Source:http://www.joachim-reichel.de/)

Through the Mandelbrot set, Benoit Mandelbrot showed that fractal structures of high complexity can be generated through recursion of simple geometric transformations, and that slight changes in the transformation algorithm cause global changes of the set (Kinnebrock, Werner 2002, p. 154). Fractals show that the generation of complexity is not bound to complex algorithms and that complex systems need not be described via complex expressions.

3.4.3 Chaos in Art

Fractals and chaos have inspired many artists to create artworks based on their principles. Philosopher Friedrich Nietzsche already saw the transformative powers that lie inside chaos that are able to yield the radically new[4]. Fractals contain always a degree of predictability and unpredictability, which

[4]"One must still have chaos in oneself to be able to give birth to a dancing star."-"[M]an muss noch Chaos in sich haben, um einen tanzenden Stern gebären zu können." (Nietzsche 2011, p. 10)

Figure 3.6: Fractal generated landscape, (Source: Gary R. Huber, 3D Nature, LLC - http://www.3dnworld.com/gallery.php?user=GHuber, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=1790607)

is handy when it comes to things that need structure and diversity at the same time, therefore they are used in the procedural generation of environments for computer graphics (shown in 3.6). Computer graphics pioneer and co-founder of *Pixar Studios*, Loren Carpenter was also familiar with Mandelbrot fractals and used the concept laid out by Mandelbrot to make his computer graphics used in many films look more realistic.[5] Today modern scenery generators like *Vue*[6] by *e-on software* and *Planetside's Terragen*[7] use fractals as part of their algorithms to create realistic looking virtual landscapes for computer games, movies and animated film.[8] The fascination of

[5] (2012). *IBM100 - Fractal Geometry.* URL: `http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/fractal/transform/` (visited on 07/16/2018).

[6] https://info.e-onsoftware.com/vue

[7] https://planetside.co.uk/whats-new-in-terragen-4/

[8] Jarratt, Steve (2014). *7 Great Ways to Create CG Landscapes.* URL: `https://www.creativebloq.com/audiovisual/7-great-ways-create-cg-landscapes-81412773` (visited on 07/16/2018).

the infinite structures of fractals have also found their way into the musical composition. The Hungarian-Austrian composer Györgi Legti said that he was influenced by the fractal geometry of the Mandelbrot set for his works *Etudes for piano*(1985-2001), *Piano Concerto* (Théron 2012).

Chapter 4

Feedback Systems in Music

The emergence of using feedback as a source of sonic expression is closely linked to the development of sound amplification technology and musical electronics (Burns and Burtner 2004, p. 5). Electronic feedback circuits themselves are the basis for the amplification of a signal, by using the principle of positive feedback to increase the volume of a signal and negative feedback for the stabilization of the circuit. The phenomenon of sonic feedback loops between microphones, guitar pickups, and amplified loudspeakers, is otherwise known as the Larsen effect. The Danish researcher Soren Absalon Larsen was the first to describe the effect of a sustained tone occurring between the electro-phonic chain of a microphone and loudspeaker, that constantly reinjects and amplifies the signal over itself in 1871 (Augoyard et al. 2006, p. 65). Acoustic feedback became a topic of artistic research in rock and pop music, as well as for avant-garde composers like Alvin Lucier, David Tudor, Robert Ashley, Gordon Mumma, and Steve Reich, during the 1960s. Feedback is an immanent attribute and core fundament to the electro-acoustic and electronic music that we are used to hearing nowadays, and some of its features are considered intrinsic for electronic and electro-acoustic music, today.
Music that is created with feedback or uses feedback, exploits and exhibits the features described in the previous section like chaotic behavior, non-linearity, and self-organization. Artists explore this features and use them as a modus operandi for their artistic expression. Since feedback is easy to obtain and difficult to control, it is an exciting method for composers and musicians to engage with complex mathematics and systems in a playful way, that has near infinite possibilities for its creative use.

4.1 Sonic Features of Feedback Loops

One of the core features of feedback is the introduction of endlessly sustained tones. Composer and electronic music pioneer Robert Ashley states that "feedback introduces sustained sounds which is one of electronics music's inherent attributes" (Holmes 2002, p. 28). An audio feedback loop will continue to oscillate and therefore create a tone or texture until the cycle is interrupted or shut off. The sustained tone is based on the resonant frequency of the system. The resonant frequency is the natural frequency a system is oscillating at, after being excited by an external force. This frequency is based on the physical properties of the system. Through feedback, the system will continue to oscillate after being excited, since the resonant frequency is re-injected back into the system. In a chaotic chase, for example, when there are multiple feedback-loops connected to each other, this oscillation can also become aperiodic. In this case, not a tone, but a texture with a changing timbre can be heard by the listener. The oscillation the feedback system settles to, inside the space state of the system, is basically a limit-cycle when it is a periodic- or a strange attractor when it is an aperiodic oscillation.

Also, the initial conditions are determining the further development of the feedback loop. In the case of an electric guitar, for example, the note played will continue to sustain through the feedback between guitar and amplifier, as long as there are no other influences disturbing the current equilibrium of the oscillation.

The work with feedback systems is characterized by the bifurcation of the attractor. Most of the musical development consists of manipulating controls of the feedback system to change the attractor qualitatively or perturb the attractor in such a way that the system gets knocked into basin of attraction inside the state space. One could say that the sonic exploration of an audio feedback system is the exploration of the state space of the system.

Another feature that distinguishes audio feedback systems from others is their dependence on the history of perturbations of the system itself. Typically the composer or performer has all possibilities for the sonic formation available at any moment, but inside a feedback system, the "future activity is limited and channeled not only by the composer's decisions, but also by the history of the audio system itself" (Burns and Burtner 2004, p. 9). Referencing Maturana and Varela (1987, p. 70), working with audio feedback systems can be thought of as some sort of evolutionary procedure, where all past happenings are constitutive for the future characteristics of the audio output. One also can take this concept further and think about history outside the time frame of the performance, but also the history of the system

encoding	*Analog/Digital*
rate	*Audio/Control*
openness	*Closed/Open*
trigger	*Internal/External*
adaptivity	*Adaptive/Non-adaptive*
interaction	*Absent/Present*

Table 4.1: Categories for Feedback System by (Sanfilippo and Valle 2012)

as a whole, like treatment and functional defects as a result of past actions that constitute it's behavior when feedbacking.
What is also unique to the work with feedback is that the connection between interface and audio output is non-linear. Depending on the current state of the system the same interaction can have different sonic results. Inside a certain configuration, the movement of a fader by one millimeter will make a big difference to the sound, while in another it might not. This makes the interaction with the feedback system quite challenging and difficult to control for the composer/performer, the output always being based on the current state of the feedback system itself.

4.2 Classification of Audio Feedback Systems

One can make several distinctions between different configurations of audio feedback systems to describe the concepts and approaches on how artists work with them. In their paper *Towards a typology of feedback systems* Sanfilippo and Valle (2012, pp. 35-36) have already provided with a good distinction between different types of feedback systems. Sanfillipo and Valle define 6 categories of a system that consist of pairs of opposition (shown in 4.1). In their model, a feedback system can have either one of the opposed features or a hybrid form. I will shortly describe the categories openness, encoding, and interaction, that are of the most relevance for the artworks discussed inside the thesis.
The category openness describes if audio information external to the system can have an influence on it. This is often achieved by the use of microphones or other sound pick-ups, that incorporate sounds from the surrounding environment into the system. This sounds can acts as sources of perturbation to the feedback system, embedding it into the sound environment of the performance or installation space.

Encoding refers to if the system is encoding the audio information either in the numerical domain of the digital or the realm of electrical current in analog systems. The main difference is that analog systems are mostly more non-linear due to their physical nature than digital ones that deal with an idealized virtual environment. Analog systems are through their non-linear nature often more difficult to control, and their results harder to reproduce but can be more diverse in their output, since their components have already a high degree of non-linearity. Digital systems, on the other hand, have the problem of digital clipping. Digital signal components often are designed to work between a float point range of -1 to 1. Once this range is exceeded the signal above or below this threshold gets clipped to the minimum/maximum of this range, which means values outside the threshold are not considered anymore. With positive feedback, where values can rise exponentially, this means that a feedback loop can quickly exceed this range, resulting in silence. In analog systems this clipping does not occur, making it easier to work with systems that use strong positive feedback loops. Also, analog components often produce residual noise that can act as a trigger and source for alimentation for a system. This noise is absent in digital systems, that means often some artificially created noise or a random impulse is needed to trigger the start of the system. In the case of an open system, this trigger can also come from an external source.
Concerning interaction, a system can either be dependent on a performer that enters the feedback loop and alters it to create tonal variations, or it is autonomous and generative, able to create his own variations from the inputs it receives, without a performer controlling the system. The latter is often found in installation works, while the former is the modus operandi for performance-based setups. The following two chapters divide musical feedback systems into systems where the feedback signal travels through the acoustic space, and systems where the feedback process happens inside an electronic or digital circuit. Feedback systems inside acoustic spaces are normally characterized by their openness since they are sensitive to their environmental sounds too. In-circuit feedback systems are opposed to acoustic ones often more closed since the feedback happens in a digital/analog circuit that is an environment that is decoupled from the acoustic space of the performance. A higher degree of openness can be achieved by those systems again by using microphones that act as sensors to the acoustic environment.

Figure 4.1: The Grateful Dead playing at Iowa State Fair, 1974. Towers of amps and speakers are considered an iconic image inside rock'n'roll culture. (Source: https://dogoneblog.wordpress.com)

4.3 Acoustic Feedback Systems

4.3.1 Amplifier Worship: From Rock music to Noise Inside the Feedback Loop

During the 1960s music festivals and venues for rock music were getting more and more popular, attracting bigger crowds of people. Though stages and audiences were getting bigger the PA-Systems[1] and monitoring sound systems for the band back at that time were not as powerful as today, this demanded more powerful guitar and bass amplifiers for the band on stage. But with the rise of volume of the amplifiers, feedback started to occur through the guitar strings getting excited by the output of the speaker and reinjecting the vibration of the string back into the amplifier over the electromagnetic

[1]PA stands for public address and means the sound system that is pointing at the audience

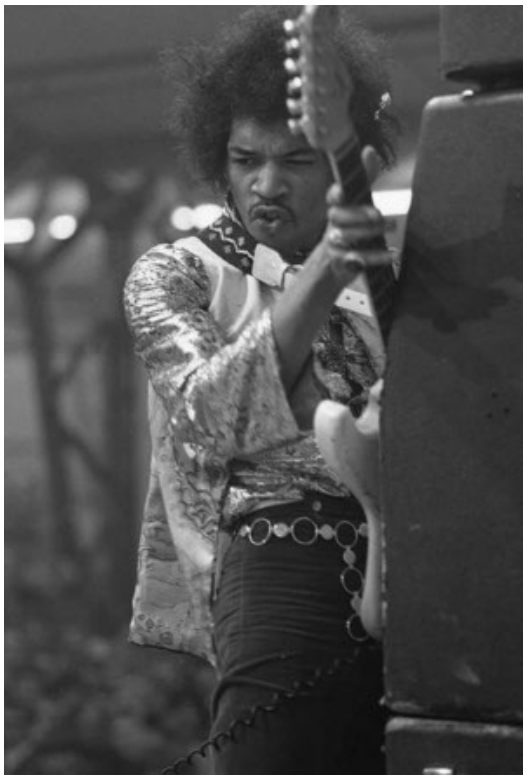
guitar pickup, leading to sustained squealing tones and noises. Some artists discovered that they could use this unintentional effect, resulting from high amplification, in a musical sense by shaping the pitch and timbre of the feedback by changing the orientation of the guitar towards the speaker and using different effect pedals and manipulating the strings, to enhance certain frequencies of the signal.
Perhaps, most famous for the early use of feedback is Jimi Hendrix's performance of the American national anthem *Star Spangled Banner* in Woodstock in 1969.[2] Hendrix uses the guitar in this performance as a feedback controller shaping the timbre and pitch of the feedback, through bending the neck, moving his guitar around and using the tremolo to change the pitch of the resonating strings of the instruments. Hendrix got so fascinated with the use of feedback in his live performances that it is said that he used masking tape during the sound check to mark sweet spots for the creation of feedback on the stage.[3] What Hendrix did was abandoning the traditional notions of playing guitar and opening up a new way of using the instrument, that has inspired many following guitarists (Burns and Burtner 2004, p. 5). Brian May, guitarist of Queen, was inspired by the use of feedback by Jimi Hendrix and Jeff Beck and built his own guitar *Red Special* together with his father to be able to create sustaining tones through feedback between amplifier and guitar. May's configuration of guitar pickups is made in a way that feedback can be shaped through switches that put the pickups of his guitar in and out of phase from each other, resulting in different behaviors when creating feedback.[4]

In 1975 Loud Reed, guitarist of *The Velvet Underground* released his album *Metal Machine Music* that would become a milestone shifting the use of the electric guitar away from the traditions of blues and rock'n'roll music, exploring new sonic territory. Made entirely from feedback created with his highly distorted guitar the album sounded unlike anything associated with this instrument before; no riffs, harmonies or hand strummed chords and melodies, but droning gritty mid-range tones and noisy textures dominate the 64 minutes long record. Lou Reed himself said he was influenced by the music of La Monte Young's Theater of eternal music, a group that created neo-classical music by improvising over sustained drone notes with

[2] () *Jimi Hendrix- Star Spangled Banner at Woodstock.* URL: `https://www.youtube.com/watch?v=MKvnQYFhGCc` (visited on 04/10/2018).

[3] () *Guitar - What Are Some Techniques to Control Feedback in a Musical Setting?* URL: `https://music.stackexchange.com/questions/2518/what-are-some-techniques-to-control-feedback-in-a-musical-setting` (visited on 04/10/2018).

[4] () *Queen Guitarist Brian May Talks about Building The Red Special Guitar.* URL: `https://www.youtube.com/watch?v=TS6bPFoCIkc` (visited on 04/10/2018).



(a) Jimi Hendrix creating feedback with his guitar by moving it close to his cabinet, Rotterdam, 1967. (Photo: Rob Bosboom)

(b) Brian May, guitarist of Queen, with Red Special. White phase switches can be seen on the pickguard under the pick-ups. (Source:https://miniguitars.wordpress.com)

non-western instruments.[5] Reed's experiments with feedback of the electric guitar lead to developments like noise music, no-wave, industrial and noise rock, that were turning their back on the traditional use of rock instruments. Inside these new experimental approaches, the guitar often was rather used as a feedback controller than a classic string instrument. The band *Sonic Youth* took Lou Reed's idea of feedback generated guitar music into their unique blend of alternative rock mixed with noise music. Some of their techniques used to achieve their sound aesthetic involves playing at high volume, unorthodox guitar tunings, dragging their instruments over stage or walking over them. Their album *Silver Sessions for Jason Knuth* is another example for feedback driven guitar work. Inside the liner notes guitarist Thurston Moore states that the album was made by turning up every amplifier in their

[5] () *Metal Machine Music - Lou Reed — Songs, Reviews, Credits.* URL: `https://www.allmusic.com/album/metal-machine-music-mw0000099717` (visited on 07/17/2018).

Figure 4.3: Drone Metal band Sunn 0))) playing at Brutal Assault Festival, Czech Republic, 2015. (Source: Dominik Matus - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=42275193)

rehearsal room to maximum and hooking up as many guitars as possible, creating a cacophonous wall of distorted feedback from the instruments to the amplifiers. The band claims leaving their instruments alone and just recording what would emerge from the instruments and amplifiers by themselves, then later going to the studio and processing the recorded sessions to sections and tracks for the album.[6][7]

Another contemporary band which takes guitar feedback as a core fundament for their music, is the experimental metal outfit *Sunn 0)))* (shown in 4.3) . *Sunn 0)))'s* music is based around droning guitar chords that are endlessly sustained through feedback created with several guitar and bass amplifiers as well as effect pedals with high gain distortion. The band is

[6] () *Sonic Youth - Silver Session (For Jason Knuth).* URL: `https://www.discogs.com/Sonic-Youth-Silver-Session-For-Jason-Knuth/release/341226` (visited on 06/11/2018).

[7] () *Silver Session for Jason Knuth - Sonic Youth — Songs, Reviews, Credits.* URL: `https://www.allmusic.com/album/silver-session-for-jason-knuth-mw0000039230` (visited on 04/10/2018).

known for playing at very high volumes[8] to increase the feedbacking of their instruments. Further, the guitars are tuned extremely low to create a very heavy guitar sound with a lot of low end. Guitarist Stephen O'Malley states that he is using a phase switch that can split the incoming guitar signal into 4 channels that have individual phase control over themselves. Through this setup, O'Malley is able to play over several amplifiers that can be in different phases from the original guitar signal, which creates rich possibilities for the tonal shaping of the resonating feedback between his guitar and the amplifiers.[9]
Today feedback is considered an iconic sound mark[10]in loud rock music since it is an unavoidable effect that is caused by the high amplification of the music. The effect of feedback is so popular that it is used deliberately as a stylistic element of the music and even led to the development of gear that enhances the creation and control of feedback. The *E-Bow*, a small handheld device, that creates feedback locally on a single string by picking up and re-injecting the signal into itself enabling controlled pitched feedback of the guitar-strings, is just one example of a wide range of devices that show rock'n'roll's fascination with the Larsen effect. The exploration of guitar feedback has also contributed to the development of noise music and more experimental approaches of rock music, that exploit the technical conditions and their limitations that are inherent to the music and show that the sound of rock'n'roll is highly electronic and dependent on electric amplification circuitry.

4.3.2 Larsen Effect in Avantgarde and Experimental Music: Exploration of Resonant Spaces and Objects

Outside of popular and rock music the Larsen effect was used by early avantgarde and electronic music composers as a medium for experimentation with electronics and room acoustics. One of the first works dedicated to the musical use of feedback is the tape piece[11] *Le Voyage*(1961-62) by French electronic music pioneer Pierre Henry. Probably one of his best-known pieces,

[8]Their Liner notes and tech riders state: "Maximum Volume Yields Maximum Results". *Sunn 0)))* plays at levels of 125db Volume, using the PA only as an enhancement for the low end of the backline.

[9] () *Stephen O'Malley Lecture (New York 2013) — Red Bull Music Academy.* URL: `https://www.youtube.com/watch?v=m-ZdB7pEvAs` (visited on 06/11/2018).

[10]Soundmark is a term used by acoustic ecologist Raymond Murray Schafer that describes a sound that is unique to a certain enviroment

[11]Electronic music composed and assembled on magnetic tape

the composition uses sounds generated through feedback as it's main material, that was then cut up and processed through tape editing techniques used by Henry (Holmes 2012, p. 58).
American avant-garde composers like David Tudor, Gordon Mumma, Robert Ashley, and Alvin Lucier based some of their works of live electronic music, installation, and performance around the notion of feedback in the 1960s. In the piece *The Wolfman*(1964) by composer Robert Ashley, a performer controlled the feedback that is established between a microphone and a loudspeaker, by standing in front of the microphone and changing the resonating room of his mouth and performing vocal patterns. Robert Ashley states that: "Feedback is a wonderfully rich and expressive voice when incorporated into music."(Holmes 2002, p. 28).
The composer Alvin Lucier dedicated most of his works to the exploration of real-time processing of sounds in resonant environments, devoting his works to the research of the phenomenon of resonant acoustics (Holmes 2012, p. 427). In many of his works, Lucier uses feedback to extract the resonating modes of an acoustic object or room to present the listener with the acoustic features inherent in the object itself. One of his most famous pieces using this principle is *I am sitting in a room*(1969). The work is based on a recording of Lucier's voice reading a text he recorded beforehand in the studio.[12] Inside the performance, the text is played back into the room and re-recorded. Then the re-recorded text is again played back into the room and re-recorded. With every iteration, the resonant frequencies of the room are amplified until the speech has transformed to the steady tones of the room's resonating frequencies. Other pieces by Lucier using this principle are: *Bird and Person Dining*(1975), *Music for Cello with One or More Amplified Vases*(1992), *Risonanza*(1982) and many others.

The Danish sound artist Jacob Kirkegaard also used the same technique in some of his artworks, to extract the resonating frequencies of an acoustic object. In *4 rooms*(2006), a CD released on *Touch Music*, Kirkegaard uses Lucier's feedback technique from a technical point of view for his own purpose. Four deserted rooms inside the 'Zone of Alienation' in Chernobyl, that were used for the communal life of the town(a swimming pool, a church, an auditorium, and a gymnasium), were chosen to create feedback recordings.

[12]"I am sitting in a room different from the one you are in now. I am recording the sound of my speaking voice and I am going to play it back into the room again and again until the resonant frequencies of the room reinforce themselves so that any semblance of my speech, with perhaps the exception of rhythm, is destroyed. What you will hear, then, are the natural resonant frequencies of the room articulated by speech. I regard this activity not so much as a demonstration of a physical fact, but more as a way to smooth out any irregularities my speech might have."

Figure 4.4: Recording setup by Kirkegaard for 4 rooms, showing the feedback chain of a speaker in the background and microphone with windshield in the front. Chernobyl, 2005. (Source:http://fonik.dk)

In contrast to Lucier's work no voice or recording is used to engage a process, Kirkegaard recorded 10 minutes of silence inside the room and played it back into the space until a soundscape of the room's resonating frequencies had evolved from hiss and background noises of the first recording procedure (shown in 4.4).[13] In another work *Phonurgia Metallis*(2009), Kirkegaard uses 3 metallic plates as a resonator, by amplifying their own resonant frequencies through a feedback loop established between contact microphones and contact speakers that are attached to the plates. Impulses from the outside that are picked up by the contact microphones get amplified and are played back through the loudspeakers, the sounds of the loudspeakers are then re-recorded by the microphones. The plates act like sensors that are sensitive to their surroundings, changing their vibration in direct reaction to the sounds

[13] () *4 ROOMS*. URL: `http://fonik.dk/works/4rooms.html` (visited on 03/21/2018).

(a) The Barons inside their Studio. (Source: calarts.edu)

(b) Gordon Mumma and Cybersonic horn from a live performance of Hornpipe 1967 at the Metropolitan Museum of Art, New York City, (Feb. 19, 1972). (Source: http://www.brainwashed.com/)

and movements inside the room.[14] Another contemporary example for the use of feedback in acoustic spaces is the British experimental electronic music group *Emptyset*. *Emptyset* uses a technique they term "re-amplification" to achieve their unique palette of sounds. In their re-amplification process, *Emptyset* places a sound system into a room, and play a sound into the acoustic space (e.g. an old mine or a deserted nuclear power plant). Several microphones are placed in different positions of the acoustic space picking up the signal filtered by the room and feeding it back into the sound-system (Sperl 2013).

4.3.3 Early Electronic Music & Cybernetics

The use of feedback systems in music began in the 1960s through the practical experimentation with audio circuits and the theoretical reflections on cybernetics and system theory (Sanfilippo and Valle 2012, p. 30). Most of

[14] () *PHONURGIA METALLIS*. URL: `http://fonik.dk/works/phonurgia.html` (visited on 03/21/2018).

this experimentation took place in the United States, where artists working with musical electronics had hardly any institutional support (Holmes 2012, p. 98) and were forced to come up with their own homemade circuits for creating electronic music. Luis and Bebe Baron (shown in 4.5a) who ran one of the first electronic music studios in the U.S. saw themselves in the tradition of cybernetics founding father Norbert Wiener. The Barons built much of their gear themselves, that was used for the composition of soundtracks and sound effects for films, or the realization of works by other composers, like John Cage, Morton Feldman, Christian Wolff, Earle Brown, and David Tudor. Bebe Baron (ibid., p. 99) remembers: "It really wasn't all like music because we were not concerned with note-by-note composition. What we did was build certain kinds of simple circuits that had a peculiar sort of nervous system, shall we say". The composer and engineer Gordon Mumma also mentions the science of cybernetics to describe his home-made audio circuit creations, the earliest created back in 1958. Mumma referred to his musical circuitry as 'cybersonic consoles' that could react to a live input of an instrument by transforming and augmenting the sound in realtime (shown in 4.5b). Mumma makes a clear reference to Norbert Wiener and his definition of Cybernetics whilst talking about his audio transformers:

> "The word 'cybersonics' derives from the greek *kybernan*, meaning to steer or guide. The work [sic!] "sonics" from the Latin sonus, pertains to sound. Cybernetics, the science of control and communication, is concerned with interactions between automatic control and living organisms. The cybersonic sound controls are derived from the sound materials themselves and applied directly to their own musical modification and articulation." - Gordon Mumma (ibid., p. 316)

Mumma's 'cybersonic consoles' used modulated feedback to create a direct response to the sound of the instrument, as well as triggering other sound-generating circuits of his consoles. In his piece *Hornpipe*(1967) the 'cybersonic console' monitors the resonances of a waldhorn and French horn played by Mumma and the acoustic performance space and adjusts the electronic circuit to complete these resonances through feedback, that become further modulated inside the circuit (ibid., pp. 424-425).

4.4 Feedback in Circuits

4.4.1 Feedbacking Oscillators

Feedback oscillators are oscillators that are operating onto their own input variables, for most oscillators this means modulating its own frequency, phase or amplitude. The technique was popularized for FM-Synthesis[15] by Yamaha who patented it in 1981 and used it in their FM-Synthesis Keyboards like the DX-Series. Inside FM-Synthesis, feedback from the oscillators is used to even out varying amplitudes of the partials produced by FM-Synthesis through the rising modulation index. Through evening out the amplitudes of the overtones, feedback can help the FM Synthesis to sound less electronic and more organic (Roads 1996, p. 242). With the increase of positive feedback strength, the partials amplitudes can even out in a way that an unpitched chaotic noise-like sound is produced from a sine wave oscillator. The partials become so evenly distributed that it results in noise; equal intensity of all frequencies of the spectrum. This way sounds with a rich overtone spectrum can be produced. This effect is used in many DIY[16] noise synthesizers that are designed to create an abrasive, chaotic and noisy sound spectrum.
The first digital feedback oscillator was described by Jean Claude Risset in the *Introductory Catalog of Computer generated sound* in 1969. Later it was implemented as a unit-generator[17] in Bell Labs as a Collaboration of Risset, Arthur Layzer, Max Mathews and F.R. Moore (ibid., p. 245). Beside simple feedbacking oscillators, where one oscillator is re-injecting the signal back into itself or into its modulator network, more interesting combinations are attainable when one is considering cross feedback between several oscillators that are modulating each other with varying strength and speed.

A very interesting synthesizer that is built around the concept of AM[18] and FM cross-feedback is *Skrewell* (shown in 4.6), a sound generator included in *Native Instruments Reaktor*. Developed by the programmer *lazyfish*, *Skrewell* uses eight freely tunable oscillators for every stereo channel that can cross-feedback into each other and uses three different oscillator modes: Implant Quad, Xung Thekh and Subtotal. Every oscillator mode uses either pulse or sine waveforms that get modulated through filters and delays to affect the spectrum of the oscillator. Though the synth can also create sounds without using feedback, things become more alive when feedback is added to the

[15] Frequency Modulation Synthesis
[16] Do-it-yourself
[17] Unit Generators are digital oscillators that constantly put out a stream of float-numbers
[18] Amplitude Modulation

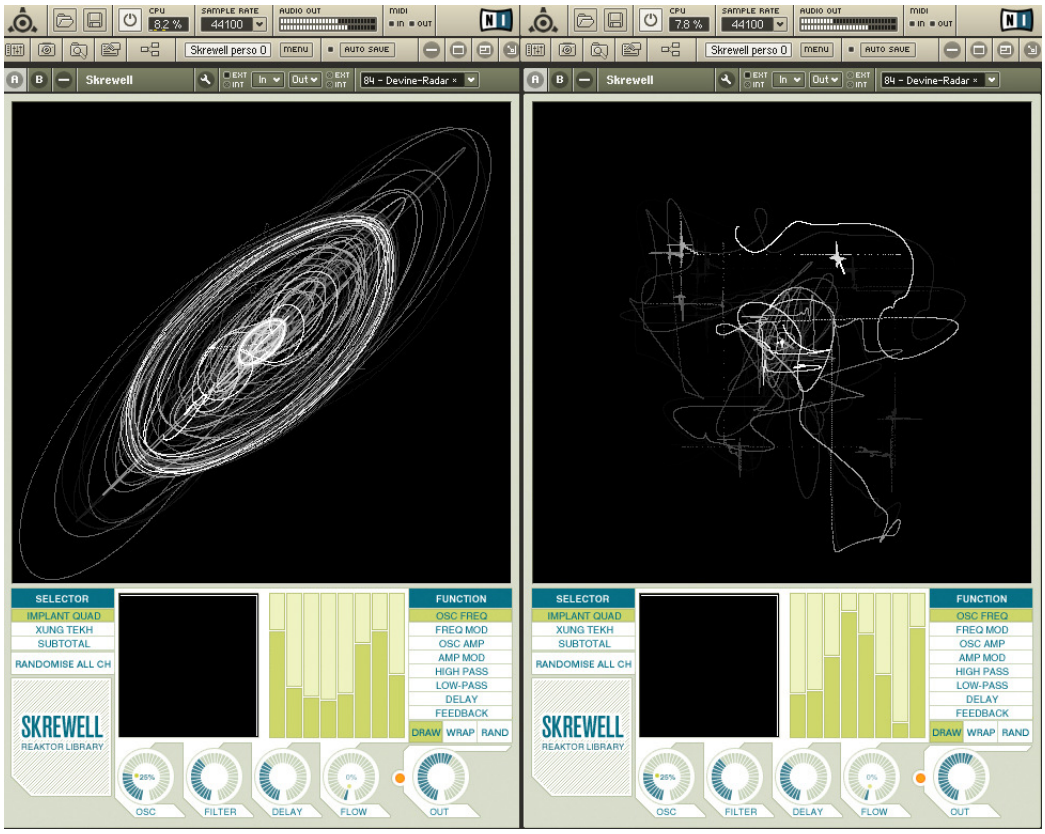


Figure 4.6: Skrewell by Lazyfish. (Source: http://www.sachagattino.com)

mix. Every oscillator can use the sum of all oscillators to feedback into its own frequency and amplitude input. Especially settings with oscillators of low frequencies are interesting since they add a modulation not only in the frequency spectrum, but in the timely evolvement of the sound. A *Skrewell* patch can play itself for a long time and show also moments of phase transition where the sound is moving in a different direction. Though it is a feedback system, by its digital nature the behavior of the instrument is very stable, so sounds can be saved as snapshots of the parameters set and recalled with the same sonic results.

Another application for feedback in sound synthesis is found inside waveguide-synthesis and karplus-strong algorithms for physical modeling of instruments and resonant spaces. Waveguides are basically a computational model of a sound wave traveling through a medium. This model is built by using a non-linear excitation source for an initial impulse for the system that is then sent into a network of delay-lines and filters. Delay time determines the time the sound wave needs to travel from the excitation source, to a source of

reflection that is a linear or non-linear filter, that passes some energy on to the output and some back into the delay-line or waveguide-network (Roads 1996, p. 282). Through the feedback from the reflecting source that gets filtered and re-injected into the system, it is possible to model string-based and wind instrument that use a resonating body to shape the sound.
Feeding an oscillator back into itself can expand the sound spectrum of an oscillator beyond the simple waveform it produces. With systems like *Skrewell* we see that digital feedback oscillators yield the possibility of saving and reproducing their sounds exactly. This gives control over the uncertain nature of feedback, while the sounds produced by the systems are still chaotic and complex.

4.4.2 Sounds from the Void: No-Input Mixing

No-Input Mixing is a common technique used by many artists in sound art and noise music. It misuses an ordinary mixing board to function as a sound synthesizer by causing the circuit to oscillate through feedback. In No-Input mixing the output of the mixing board is routed back into one of the input channels to create an in-circuit electronic feedback loop, that will start to oscillate while raising the gain of the preamplifier and output. The hiss and noise that is produced by the circuit is getting amplified and is then ordered by the feedback resulting in an oscillation, that is an audible tone produced by the mixer.
One of the first artist to work with No-Input mixing extensively, was David Lee Meyers aka *Arcan Device*, who did some pioneering work in the field, by building his own feedback devices and mixers (shown in 4.7), though David Tudor's work with his self-made electronic music modules in the 1960s already involved No-Input mixing by interconnecting the modules back into themselves (O'Connell 2008). Meyers describes his encounters with feedback mixing as follows:

> "Finally I settled on Digitech 7.6 second delays, bought four of them and set about to build them into a self contained console. [...] This resulted in, to my knowledge, the first 'matrix mixer' ever created. Nowadays this seems more commonplace, but at the time it was unique - a mixer which could feed multiple effects and return their outputs to all others, plus themselves - i.e., feedback loops. As soon as I powered up the layout, I immediately discovered that I needed no input: the delays themselves created their own sounds."[19].

[19] () *David Lee Myers Interview.* URL: `http://www.ownzee.com/post/5458/david-`

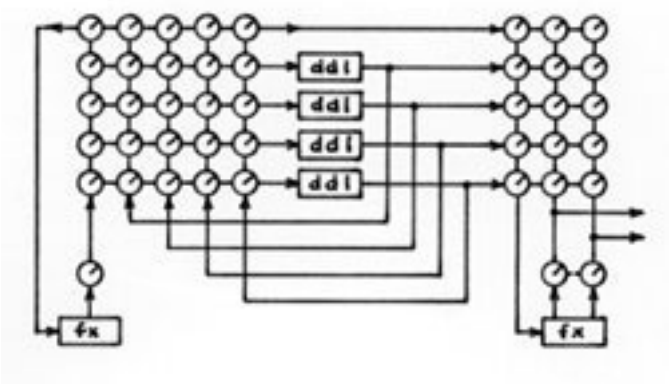


Figure 4.7: Diagram from David Lee Meyers for his matrix mixer design. (Source: https://www.pulsewidth.com/)

In most No-Input mixing setups, mixers with several send channels are desirable since they allow for flexible routing between the different channels. A send channel allows routing a certain amount of the signal of an input-channel to the dedicated send channel. In common mixing situations inside a recording studio or a live-situation, this is used to route the input signal to sound processing units that add an effect to the incoming signal. These sound processing units normally have their own respective channel on a mixing board called the return channel. However for No-Input mixing the return channels remain unnecessary since the input channels are used as the return, which allows for routing back the signal into itself; creating feedback.
The matrix mixer (shown in 4.8) is a special case where every input channel can route it's output to every other input channel inside the mixer, that allows for complex interconnected webs of feedback loops, resulting in rich and often unpredictable chaotic soundscapes. With this technique one can have several channels containing different feedback loop configurations that can also modulate and blend into each other, making it an expressive and challenging performance instrument.

No-Input mixing exploits the non-linearities of electronic components to create its unique sound and behavior. The pitch and timbres in No-Input mixing are controlled by the amount of signal sent back to the input channel and it's amplification, as well as using the equalizers included on many mixing boards to enhance certain frequencies of the spectrum of the feedback loop. The non-linear behavior of the electric components differs from mixer to mixer that means every mixer sounds different when used for No-Input mixing, while the interface and method of operation stay mostly the

`lee-myers-interview` (visited on 11/07/2017).

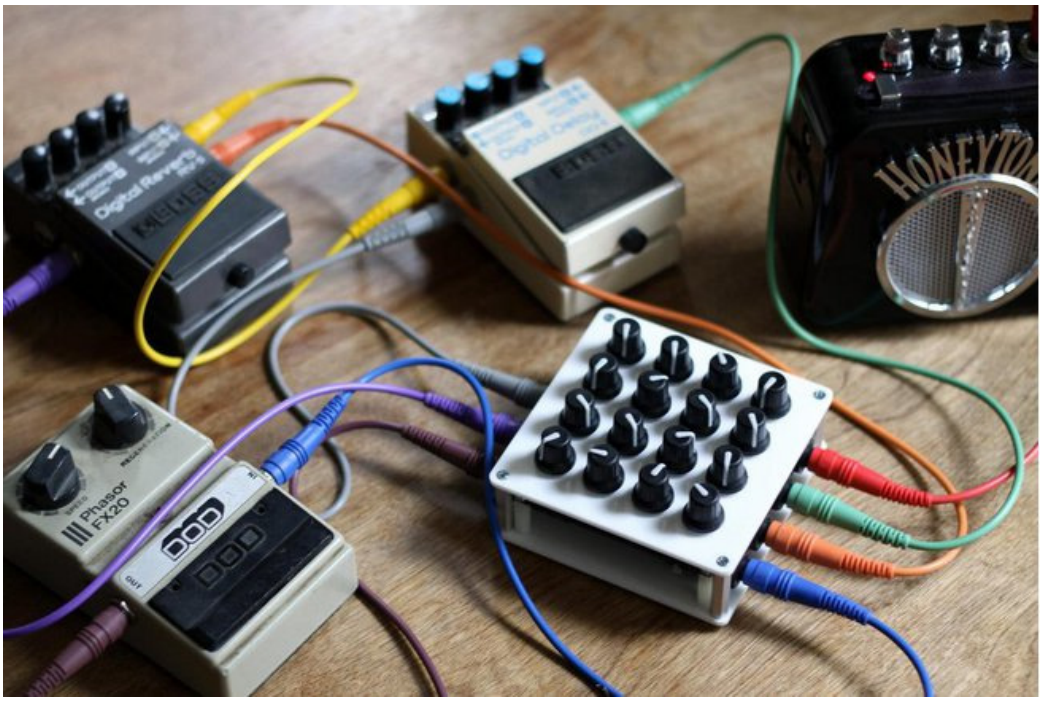


Figure 4.8: Matrix Mixer by Xiwi Electronics with hooked up effect pedals. (Picture: Xiwi Electronics)

same. This non-linear behavior is what makes No-Input mixing such a delicate and interesting matter, and is also the reason why sometimes cheaper gear is more interesting to work with than more expensive equipment. While the more expensive mixers try to achieve a more linear behavior by using better components for their circuits, the components of cheaper mixers often expose more of an irregular behavior. Also old and worn-out gear can show surprisingly interesting behavior through broken connections and dirty potentiometers making a strange non-linear curve of electrical resistance. I myself have used a wrecked *Zeck MD 10-14* for many years that creates a lot of noise by itself. This behavior depends also on the personal preferences of the artist and purpose of feedback mixing. Some artists would prefer a 'clean' mixing board that doesn't expose too many surprises and is precisely controllable. The sound-artist Christian Carrier made an arrangement of Arvo Pärts *Fraters* for No-Input mixing board played on an *Allen & Heath GL2400-40* Console at his residency at *OBORO Art Center*, Montreal 2011.[20] The piece was later put on stage together with a viola accompaniment. The

[20] () *Fratres / OBORO < Christian Carrière*. URL: `http://www.christiancarriere.com/works/fratres-oboro/` (visited on 03/29/2018).

Figure 4.9: Toshimaru Nakamura performing with No-Input mixing board. (Source:https://www.tokyogigguide.com)

performance of such a piece would be unthinkable with a mixing board that would not be precisely controllable by the performer.
While some artists work with the pure sound of No-Input mixing, by directly connecting the outputs of the mixing board to its inputs, some other artists like to add another layer of complexity into their work by putting signal processing units like reverbs, phasers or filters between output and input of the feedback loop. These signal processors transform the sound often in mathematical complex ways, resulting in richer and more complex soundscapes when fed back into themselves. Japanese sound artist and improviser Toshimaru Nakamura (shown in 4.9) has been working with No-Input mixing since the mid-1990s and released nine solo albums of music created with this technique, while also being an avid collaborator and improviser with other artists. Nakamura uses guitar effect pedals and other signal processors inside his feedback loops to create his minimal and abstract music that is fragile and full of life at the same time. For Nakamura it is the unpredictability of his instrument that "requires an attitude of obedience and resignation to the system and the sounds it produces, bringing a high level of indeterminacy and surprise to the music".[21]

[21] () *Bio Toshimaru Nakamura.* URL: `http://www.toshimarunakamura.com/bio/` (visited on 03/29/2018).

4.5 Feedback-Systems and Improvisation

4.5.1 Improvising with Feedback Systems: Confronting the Unknown /Systems as Scores

Feedback systems can be challenging performance instruments that are difficult to fully control for the performer, due to their non-linear behavior and circulatory iterative process. As feedback musician, Toshimaru Nakamura states:

> "You can't totally control No-Input music because it's all about feedback. Things like turning the tuning knob even by one millimeter make a big difference to the sound.[...] It's like sculpture. You shape the feedback into the music. It's very hard to control it. The slightest thing can change the sound. It's unpredictable and uncontrollable, which makes it challenging."[22]

The behavior of feedback systems often suggests a more improvisational approach towards the music than creating fixed compositions that follow an exact score. The notion that a feedback system is due to its non-linear nature and evolutionary iterative history, never totally controllable, makes it hard to play and perform a piece several times in the same manner, especially when there is acoustic feedback involved that is sensitive to the acoustics of the performance space. This uncertainty suggests another approach, the approach of designing systems, that once they are put together can unfold a performative potential to create a musical work. The composer is here focusing more on the design of interactions by putting together a system, instead of writing a score that should be followed accurately.
The works of the Sonic Arts Union consisting of composers Gordon Mumma, Alvin Lucier, Robert Ashley, and David Behrman, were often built around the idea of the exploration of a system during a performance (Tomas 2016, p. 1). The Sonic Arts Union was continuing the approach of David Tudor building their own musical circuits to produce works based on their circuitry. Alvin Lucier describes that inside many works of the Sonic Arts Union the score was inherent inside the circuitry of the system. The performance of the piece becomes then an exploration of the sonic possibility and constraints of the system designed by the composer.
In a performance with a feedback system, there are two entities engaged in the production of the piece, the performer and the system. Composer Nicolas

[22] evilpaul (). *No Input.* URL: `https://www.youtube.com/watch?v=Tl8IMc-8-N8` (visited on 04/09/2018).

Collins explains it like this:
“”[W]e accept the machine as a collaborator, rejoice in its inexplicable intransigence and, like Michelangelo finding the figure in the marble, pause to listen to the composer inside the electronics.” (Collins 2004, p. 1)” Due to its autopoietic nature, the system becomes self-organized and autonomous, an entity that can display itself without the need of a composer or a composition, which can only reveal themselves to the performer and audience inside the present moment itself (Tomas 2016, p. 1). In the tradition of John Cage's chance compositions to transgress personal musical constraints like culture and personal taste, working with the chaotic uncertainty of feedback systems can have a similar effect, making the discovery of novel sounds possible through the act of improvisation. As David Tudor said: “I try to find out what's there not to make it do what I want, but to release what's there. The object should teach you what it wants to hear” (Collins 2004, p. 1). Like in other performative practices the focus of inquiry of this practice then becomes, ”the temporal aspects of art as a durational process of organic unfolding” (Shanken 2002).
Though the feedback system is autonomous and could also create sound in the absence of the performer, normally in a performance of a piece there is another feedback loop established between system and performer. This feedback loop acts as an exchange of information and actions, where the performer is constantly listening to the system and setting actions that find it's way into the system and the system is responding to the change. The approach of working with feedback systems can be more seen as a setting where the performer is influencing the system, rather than controlling it, acting as a trigger, modifier, and perturbator (Burns and Burtner 2004, p. 9), (Sanfilippo and Valle 2012, p. 35).
Another feature that distinguishes working with feedback systems, compared to working with instruments, synthesizers, and DAWs[23], is the history of perturbations that define the sonic output of the feedback system. The same control settings inside a feedback system will produce different sonic results depending on the history of perturbations. Instead of having all control over the system, the performer is dependent on its state for his future actions. This again gives the performer more the feeling of influencing the system than controlling or commanding it. In improvisation with feedback systems, the present sound is the consequence of the history of past actions.

Figure 4.10: Musicians improvising at Improcon 2018 in Graz. (Photo: by the author)

4.5.2 Free Improvisation as a Self-Organizing System

Free improvisation is a musical practice that focuses on the spontaneous creation of music without rules. The movement emerged in the early 1960s with the claim of musicians questioning the rules governing musical language. Its origins can be found inside the improvisational traditions of jazz music, as well as in the sonic developments in avant-garde and experimental music since the beginning of the 20th century.
In free improvisation there is no underlying structure like in Jazz or Classical Music, that is used as referencing point guiding the improvisation; all production of sounds and noises are permitted at any moment of the performance; a concept that was also influenced from the live improvisation of electronic music pioneered by John Cage, David Tudor, Alvin Lucier, David Behrman and Gordon Mumma (Holmes 2012, p. 412).

> "Unlike jazz, which often deals with improvisatory rules in a kind of gamelike exchange of modes and melodies, electronic music often lacks the qualities of rhythm, harmony and melody, many

[23]Digital Audio Workstation

> jazz musicians rely on. Instead electronic music improvisation is largely based on the spontaneous modification of non-pitched aspects of sound: the shape of the envelope, timbre, rhythm, layers or filtering, effects(echo, delay, ring modulation, etc.), amplitude and duration. A seasoned improviser learns how to listen to many layers of sound activity as part of a performance." (ibid., p. 416)

Guitarist and improviser Derek Bailey (1993) calls free improvised music, non-idiomatic with no stylistic commitment where "[d]iversity is it's most consistent characteristic". Referring back to Roy Ascott in a previous chapter it is this diversity that also implies a form of unity and defines the nature of this art form (Ascott 2002, p. 1). But since there are no rules how can coherent patterns emerge from within this practice or mode of operation? The concept of feedback and self-organization can help us to understand the processes happening inside free improvisation.
In free improvisation, musicians are connected to each other through an auditory and visual feedback loop, where every local action or non-action a musician takes affects the global soundscape of the improvisation and at the same time every musician is connected with his instrument through a haptic/visual/auditory feedback loop. As we have discussed earlier feedback is enabling self-organization. A group of freely improvising musicians can be seen as a self-organizing system, where sound is the structure that is realized out of its organization; the organization referring to the musicians involved and instruments played. The performers act as autonomous entities that join and separate to parts of the system, meaning that the performer doesn't need to pay attention to every detail, and can also play 'against' the music acting as a perturbator. Still, the group of performers appears as an inseparable class, namely the producers of sound, whose action become so tightly coordinated and their decisions seem so seamlessly intertwined, that they behave like a single synergistic unit rather than a collection of individuals (Walton, Richardson, and Chemero 2014, p. 20). The performers that become a self-organizing system themselves are coupled to function as to maintain one another's order, as well as the constraints that potentiate the unit itself. Free improvisation is therefore, a non-hierarchical, non-linear and non-deterministic dynamic process like chaotic behavior, but where the attractor is continuously changing its shape. Structure of such a system is subjected to constant change and will not settle into an equilibrium until the improvisation is over, like inside the ontogenesis of an organism (Maturana and Varela 1987, p. 84). Maturana and Varela (ibid., p. 89) call this system of coupled self-organizing systems higher or second-order autopoiesis. Improvising groups work like an higher-order autopoietic system with constant

structural mutations from perturbations of the musicians, but keeping the autopoietic organization that enables the production of sound as a group intact. As in an autopoietic system, the musicians are a source/trigger of perturbations that can lead to mutations. Actions in free improvisation are not obliging effects or instructions to the music, this again stresses the non-hierarchical organization of free improvisation. Referring to improvisation in performance art Erika Fischer-Lichte (2004, p. 62) calls it an experiment that explores the functioning of the autopoietic system and the underlying feedback loop, a play with different variables, factors, and parameters that is open-ended.

Also, coincidence and randomness play an important role inside improvisation. Warren McCulloch (2003, p. 723) states that, "the best way to find out what an unknown machine did was to feed it a random input". This statement is also true for free improvisation when it is seen as an unknown machine or black box, where the output and outcome is unclear. Through the amplification of positive feedback, actions that are not intended to signify, can quickly grow and become a musical sign of the soundscape produced, by the collective ordering process of the group. Coincidences and errors are treated as sound events that have to be ordered inside the performance of free improvisation. For researcher and musician David Borgo, who has studied the connection between cybernetic theory and improvisation, exactly these errors allow for the generation of new musical meanings, and are crucial to the exploration and discovery of new musical forms of expression (Walton, Richardson, and Chemero 2014, p. 17). As Gregory Bateson says: "All that is not information, not redundancy, not form and not restraints —is noise, the only possible source of new patterns." (Bateson 1967). This sound events which are not intended to signify can also be produced by an event that is external to the autopoietic unit of the performers; namely the environmental sound of the space the performance takes place in. From my own personal experience as an improviser, I can say that this true. Attending the ImproCon in Graz in 2018 (shown in4.10), I remember listening to all sounds around me as part of the performance. My attention had shifted, treating all sound events as musical events of the performance. That suggests free improvisation as an open format that is in constant exchange with its environment, where the lines between the performance and non-performance become blurred; the environment and autopoietic unit are influencing, perturbating and mutating each other.

Chapter 5

Artistic Practice & Personal Projects

My main musical work is based on improvisational compositions that are centered around a set of themes that can be explored during a performance. Working with feedback is an important parameter of the music for me; this approach gives me the possibility to explore the sound of the system or a set of themes in the present moment, responding to the room and state of the music. Most of my performances are based around a certain setup that uses two to three feedback loops with live inputs. The setup has developed itself over the years by trying out different configurations that created appealing sonic results, while they were still controllable in a musical sense. While the input signals change from project to project, the feedback configuration has stayed similar. In most works, I either use external triggers from other sound sources to engage a feedback loop, or the residual noise of the analog components. Both ways are different to work with; while I use the residual noise method for the creation of sustained sounds, I mostly use external triggers as rhythmical elements to structure the feedback and shape its tonality based on the incoming signal.

5.1 Musical Setup

For most of my performances, I am using a mixer setup, which allows flexible routing of feedback between two or three dedicated feedback channels. I am using a slightly wrecked *Zeck MD 10-14* Mixing Desk, that features six mono and four stereo channels, with the possibility of one monitor and one aux routing per channel. It also has a built-in digital effect section, that can be routed to the monitor channel, which allows feedbacking the built-in

effects over the monitor channel. While channels one to eight are dedicated to sound sources that are fed into the mix, I use channels nine and ten as my two main feedback channels that can re-inject their signals back and between themselves. This is done by connecting the output of the monitor send into channel nine and the output of the aux-send into channel ten(shown in 5.1). In my setup, I use guitar-effect pedals, in conjunction between the output of the aux and monitor send and their input channels to add sources for further manipulation and more non-linearities of the signal. For the monitor send I use a *Digitech BP80* multi-effect pedal. The *BP80* is a multi-effect pedal for bass guitar that features an amplifier simulation, equalizers, a noise-gate, delay, reverb, compressor, filters and modulation effects like a pitch-shifter, chorus, phaser, and vibrato. It also features an expression pedal that can be tilted to control parameters of the effects in real-time. The unit provides the saving of snapshots of different combinations of effects, that makes it easy to switch between them. In my setup, I use my self-programmed snapshots that create appealing and interesting sounds when fed back into themselves. Pitch-Shifters and their quality of creating sounds that reach from endlessly ascending spiraling Shepard tones[1] to abrasive chaotic noise attacks by increasing feedback strength, are one of the most frequently used effects in this setup. Especially used in conjunction with feedbacking reverb from the built-in effects unit, morphing and self-developing textures can evolve that sing their own song autonomously. For the second feedback channel, I am using a *Boss DD6* digital delay unit. This enables me to delay the feedback process and control the evolvement of the feedback over time, as well as tuning it to a certain pitch, depending on the delay length. Both feedback channels also make heavy use of the built-in channel equalizers that enables to enhance high, mid or low frequencies of the feedback. By enhancing certain frequencies inside the feedback loop I am able to manipulate the pitch and timbre of the feedback.
One of the most fascinating aspects to me is how former states are influencing the further behavior of the system. The same settings between the effects and channel routings can produce different results depending on what happened before. Unlike a real synthesizer that just produces sound, this machine is shaping its own history based on past actions.

5.2 Setup in Practice

In my musical practice, I basically use the same feedback configuration of the mixing board but with different input signals that are fed into the feedback

[1] Psychoacoustic illusion of an endlessly ascending pitch

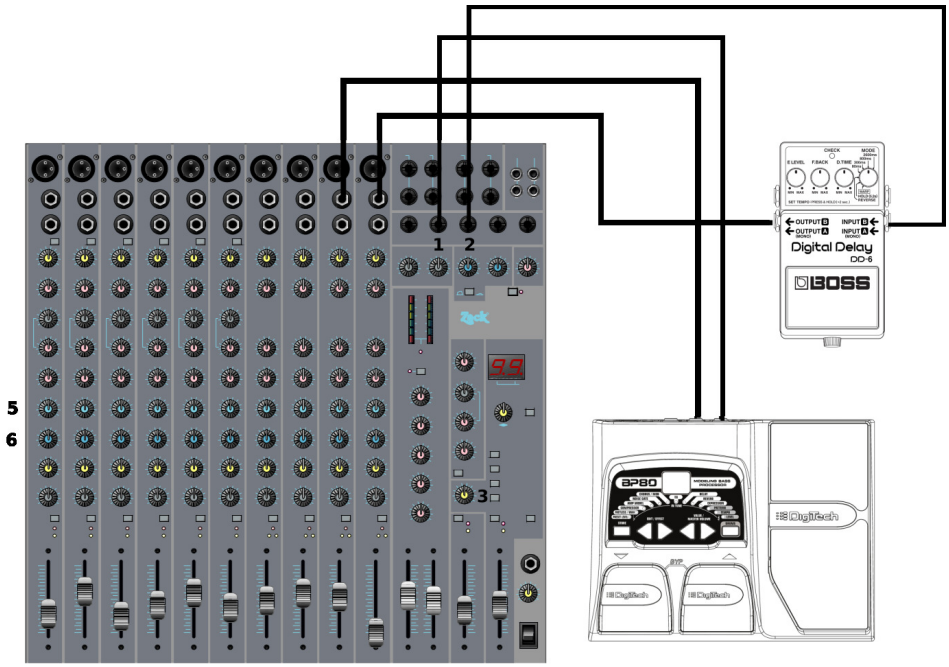


Figure 5.1: Diagramatic Wiring of the Standard Setup with most crucial feedback controls: *(1)Monitor Send Out, (2) Aux Send Out, (3) Effect to Monitor, (4)Monitor Send, (5) Aux Send.* (Diagram by the author)

loop. The input signals work as a perturbator of the feedback loop, that often stabilizes into a periodic oscillation after a certain amount of time after the perturbation. But what interests me in music the most is the aperiodicity and irregularity where it starts to sound alive and non-repetitive.
My solo project morast is currently based around the exploration of rhythm and sequencing feedback. In this setup I use a laptop running the Pure Data dataflow programming language, with a multichannel audio interface that has connected six of its outputs to my mixing desk. Pure Data is used for creating polyrhythmical structures based on samples and delay units that are routed to the mixer. From each of this six channels, I can route any amount of the signal into the feedback channels. Depending on the source of input it affects the development of the feedback as well, since the initial spectrum is involved in the evolution of feedback. Often I use a technique where I am 'pushing out' the feedback of it's designated channel, by sending a signal of very high strength into the feedback loop. When the signal strength of the incoming signal exceeds the strength of the feedback loop, the sound of the feedback gets lowered in volume and replaced by the arriving signal. Once the signal decreases in gain the feedback comes back into the channel, cre-

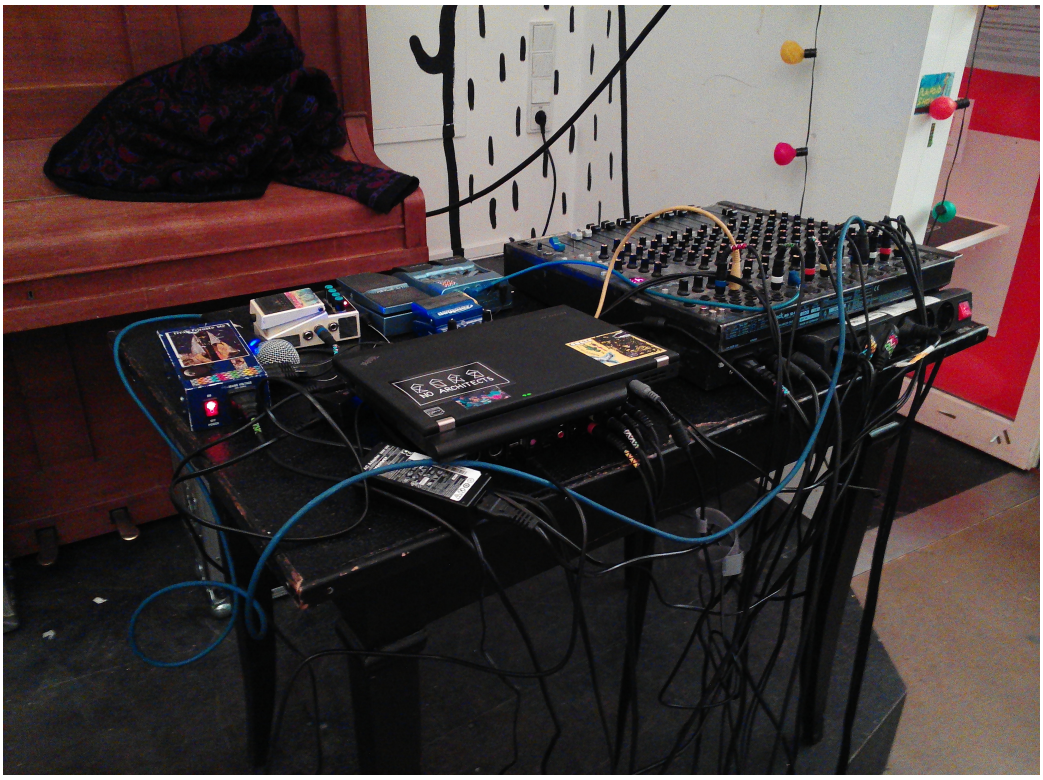


Figure 5.2: Picture of a morast live setup, with mixer, laptop and feedback effect units. (Photo: by the author)

ating a quasi sidechaining effect[2]. Mostly this is used in conjunction with a signal that has a sharp attack and a slowly decaying envelope like a bass-drum. The feedback is pushed out of the channel and slowly builds up again. This technique can also be used to push the oscillation of the feedback loop onto another attractor in the state-space, changing the timbre of the oscillation. The way the setup up works allows for the laptop to stop sequencing or even to crash, but the feedback loops continue running inside the mixer. This is handy for creating breaks or changing the tempo; one can play and modulate the current sound of the feedback loop, that has built up in one of the feedback channels through the previous input signals.

Together with my long-time musical collaborator Anna Sophie Adelt aka *States of Clay*, I've made several recordings and many live shows under the pseudonym *MHUF* aka *Mit Händen und Füßen* (shown in 5.3). Also this

[2]Sidechaining refers to a compressing technique, used in music production where the average of a signal is used to control the gain of another signal. The technique was used heavily in house and techno music to create the pumping sound of the kick pushing out other sounds to make it more present in the mix

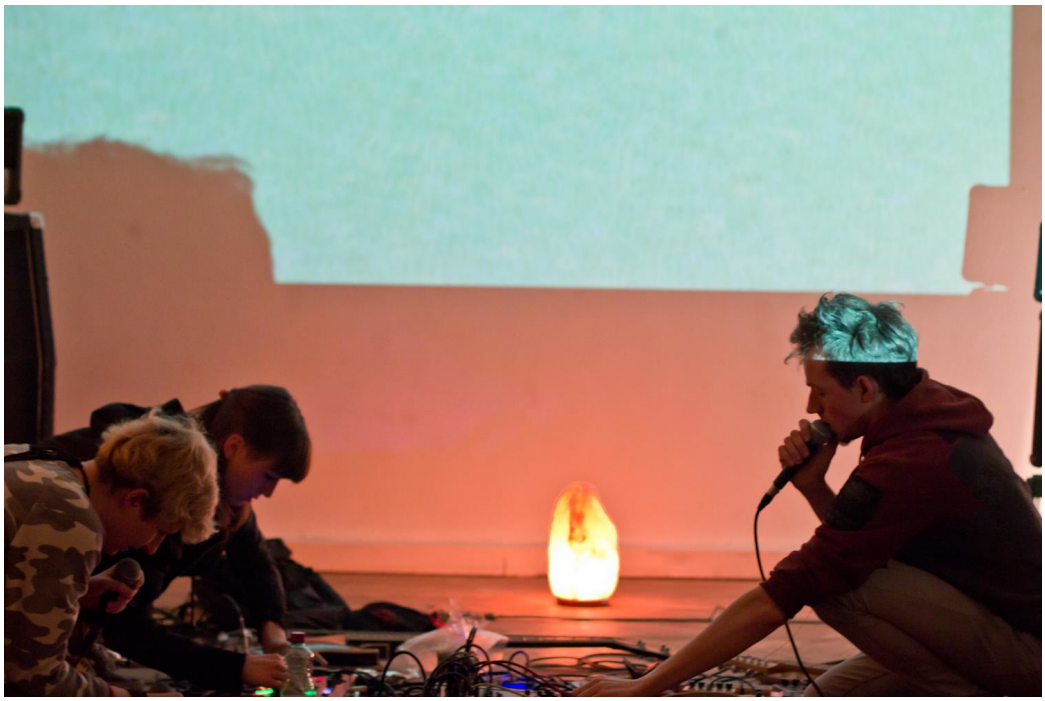


Figure 5.3: Mit Händen und Füßen guest appearance by Abu Gabi, Live @ Holzhaus, Linz 2015. (Photo: Verein das Holzhaus, http://www.dasholzhaus.at)

band is mainly based on free improvisation. I use the same feedback configuration for the send and aux channels, but with an electric guitar and a microphone as inputs into the mixer. In this setup, I use the electric guitar and the microphone as a feedback controller since they are able to pick up sound waves and electromagnetic fields making an acoustic feedback loop outside the mixing board possible. The guitar or microphone as a feedback controller is an interesting and challenging musical instrument that is sensitive to spatial movement and position; one is able to control the sound of the feedback by changing one's position related to the loudspeaker which makes it a very interesting and embodied medium of expression. Through the use of effect pedals and equalizers of the mixing board, I can make adjustments to the sound produced by the feedback. That means I can dial into another sound, that I can then again manipulate with the microphone. The possibilities are rich but the interaction with the microphone or guitar stays the same; the microphone and pickups can be used to control different sounding feedback loops.

5.3 Autopoetic Drawings

As a visual artist, I use similar processes as described in the self-organizing process of free musical improvisation to create my visual artworks. I approach drawing without any intention other than drawing itself and start by applying some freely formed lines and shapes. Between the drawing and me a visual feedback loop is constructed, that enables a dialogue between the drawing and me. The drawing is representing the subconscious part of my self, on the other side is the conscious perception of the image. It is the subconscious part of the self that offers something that is then perceived and brought forward by the conscious self inside the process of further drawing. The visual feedback between the drawing and me engage a self-organizing process that is the driving force behind the creation of the drawing. I see myself in the tradition of artist, writer, and occultist Austin Osman Spare that was concerned with automatic unintentional drawings as a method to express the subconsciousness side of the self. As Spare states: "Art is the instinctive application of the knowledge latent in the subconscious (Spare 2013, p. 236).".

Figure 5.5: Automatic drawing by Austian Osman Spare. (Source: Austin Osman Spare: Gesammelte Werke 1905 - 1927)

Spare's technique of automatic drawing offered him a short-cut to inspiration and a way to explore his self beyond the notion of his consciousness. His main goal was to create art in a primordial sense for him, beyond the imprinting of society and personal history or habits, to experience some form of transcendence, in which the true nature of oneself can unfold. Spare created blueprints for his drawings in a state of absent-mind or trance until shapes would arise that would attract his attention (ibid., p. 246), which were then shaped into Spare's personal mystical and symbolic visual language. Spare said that the mental mechanisms for this drawings were the same as they appeared in dreams and psycho-neurotic symptoms that enables sudden free association and inspiration. Though Spare called his drawing technique *Automatic Drawing*, I refer to it as autopoietic drawings rather than automatic, since the term au-

tomation is associated with machines and prepared routines and mechanisms, while the concept of autopoiesis conceived by Varela and Maturana refers to the organic development of organisms and life-forms that seems more fitting for describing the process of creating visual art. The process of making art becomes here a method for exploring the black box of the self, leading into the depths of the subconsciousness and connecting to the mythical and symbolic nature of man. Drawings created by the author with the autopoietic method can be found in the appendix of this thesis.

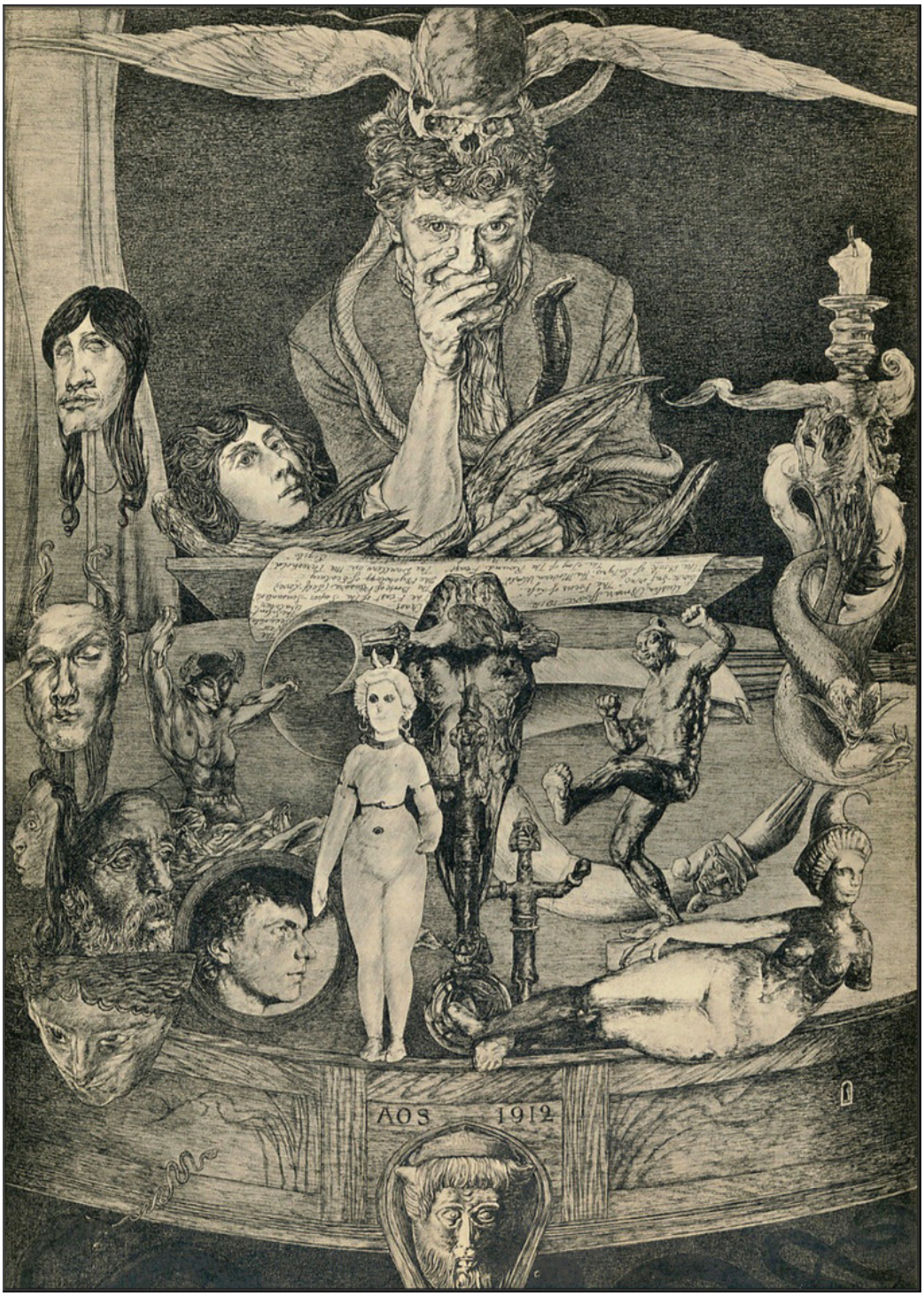


Figure 5.4: Death Posture(Frontispiz), Selfportrait with dolls by Austin Osman Spare. (Source: https://theartstack.com/)

Chapter 6

Conclusion

During the course of writing this thesis, I got a deeper insight into the phenomenon of feedback from a scientific perspective concerning the concepts of chaos, autopoiesis, and self-organization, that are the reasons for its fascinating behavior. On the other hand, I tried to trace a line from its emergence as a scientific model inside the science of cybernetics, to investigate the convergence of cybernetics and media art in the 1960s, the use of feedback in electronic experimental music, its use as a stylistic element in rock'n'roll and as a model to understand the mechanisms inside free improvisation. Now after this research, is see my own work embedded in a larger body of theories, works and artistic practices: cybernetics, chaos theory, fractals, rock'n'roll, experimental electronic music, free improvisation, and Spare's Automatic Drawings.
Feedback loops in my artistic practice reach beyond a mere coupling between microphones and loudspeakers, amplifiers and guitars, the feedback loop is offering itself as a theme, method, and concept; a modus operandi for my artistic explorations. Through the non-linear nature of feedback, my artistic process is uncertain and experimental, playful and open. I identify with an experimental approach to art, especially as it was practiced by American electronic music pioneers like David Tudor, Gordon Mumma, and Robert Ashley. In their do-it-yourself approach, art became a playful exploration of systems, circuits, communciation, and the underlying feedback loop; the exploration of the constraints of a technical system, which output was unknown. These artists were not only exploring new sonic territory that defied any traditional musical approaches but also were the first to perform live improvised electronic music in front of an audience. This had a remarkable influence on the development of free improvisation and experimental music.
Feedback systems through their sensitivity to initial conditions and their self-organizing nature suggest more for an improvisational approach, an ap-

proach that is characteristic for post-modernity and avant-garde movements, where the focus of art becomes the exploration of the underlying feedback loop of a system. Working with feedback loops is therefore connected to me with the practice of free improvisation and performance, at the same time feedback can provide us with useful analogies to understand the collective ordering process of free improvisation and non-idiomatic and non-hierarchical production of sound.

In my personal artistic process errors and uncontrollable aspects are seen as chances, that create new possibilities that reach beyond the controlled aspects of the self. Like in the autopoietic ontogenesis after Maturana and Varela (1987, p. 92), errors and deviations from the norm are the reason for diversity of life. Uncontrollable situations are exceptional situations, but yield the possibility for man to surpass himself. The work with feedback requires deep humbleness and respect from the artist towards the chaotic forces of the unknown, be it a machine, a human or another self-organizing system. Confronting the unknown means transgressing ones own habitual patterns and offering oneself to the unfamiliar, which leads the artist to experience the new and the emergence of constant novel self. The artistic process becomes an endless devouring loop of the descent and rise of the conscious and subconscious mind, symbolized in the image of the ouroboros, the snake eating its own tail (Becker 1995, p. 211). The non-linearity of the feedback loop defies the determinism of the conscious imagination, addressing the intuitive and subconscious aspects of the mind, where environment, space, time and the self, come into a dialogue and engage in a process of organic unfolding of the artwork. Like in Lucier's work, feedback is used to explore features inherent, but often hidden, in space, machines, objects, systems, and one's own personality through a durational procedure. Working with feedback as an artistic method for sound production and performance, therefore, feels very natural to me.

The auditive fractal dimension of feedback loops holds rich sonic territory to be explored by the artist. Like fractals that are capable of representing a variety of natural objects visually, feedback loops can also be used to create sounds that are organic and alive, and not static. These auditive feedback systems can be built easily from bottom-up by interconnecting parts, while the sounds produced can be complex and abstract, making it a playful way to work with something that is mathematically so complex that it can't be anticipated. Playfulness and curiosity are important aspects in my process, to quote Friedrich Schiller: "Man only plays when he is in the fullest sense of the word a human being, and he is only fully a human being when he

plays."[1]
For me, the thesis was brought together a lot of loose threads that now seem interwoven through the research of my thesis: improvisation, chaos theory, experimental electronic music, the legacy of rock'n roll, media art and automatic drawing. The research provided me with a theoretical fundament for my work and a positioning inside the described theories and practices. In the future, I will continue to work further with the principle of feedback and free improvisation since it has always been inspiring and magickal[2] to me. The mentioned artists and methods utilizing feedback for sound generation have inspired me again to build new systems for feedback routing and synthesis using analog and digital components. This hopefully will result in new performative potentials for the improvisation in solo performance and with others. Always I am curious what the future holds and what is to be experienced in the endless recurring feedback loops. So let us lift the anchor and set sail on the winds of chaos to depart into the unknown!

[1] Zerzan, John (). *On the Aesthetic Education of Man–Friedrich Schiller Excerpts from Schiller's Volume of the Same Title: Pp. 27, 29, 33, 35, 43, 107. Compiled by John Zerzan in His Book Against Civilization.* URL: `http://www.primitivism.com/schiller.htm` (visited on 09/19/2018).

[2] I use the word magickal instead of magical since Aleister Crowley used the word magick to differentiate the occult from the act of performance and show magic

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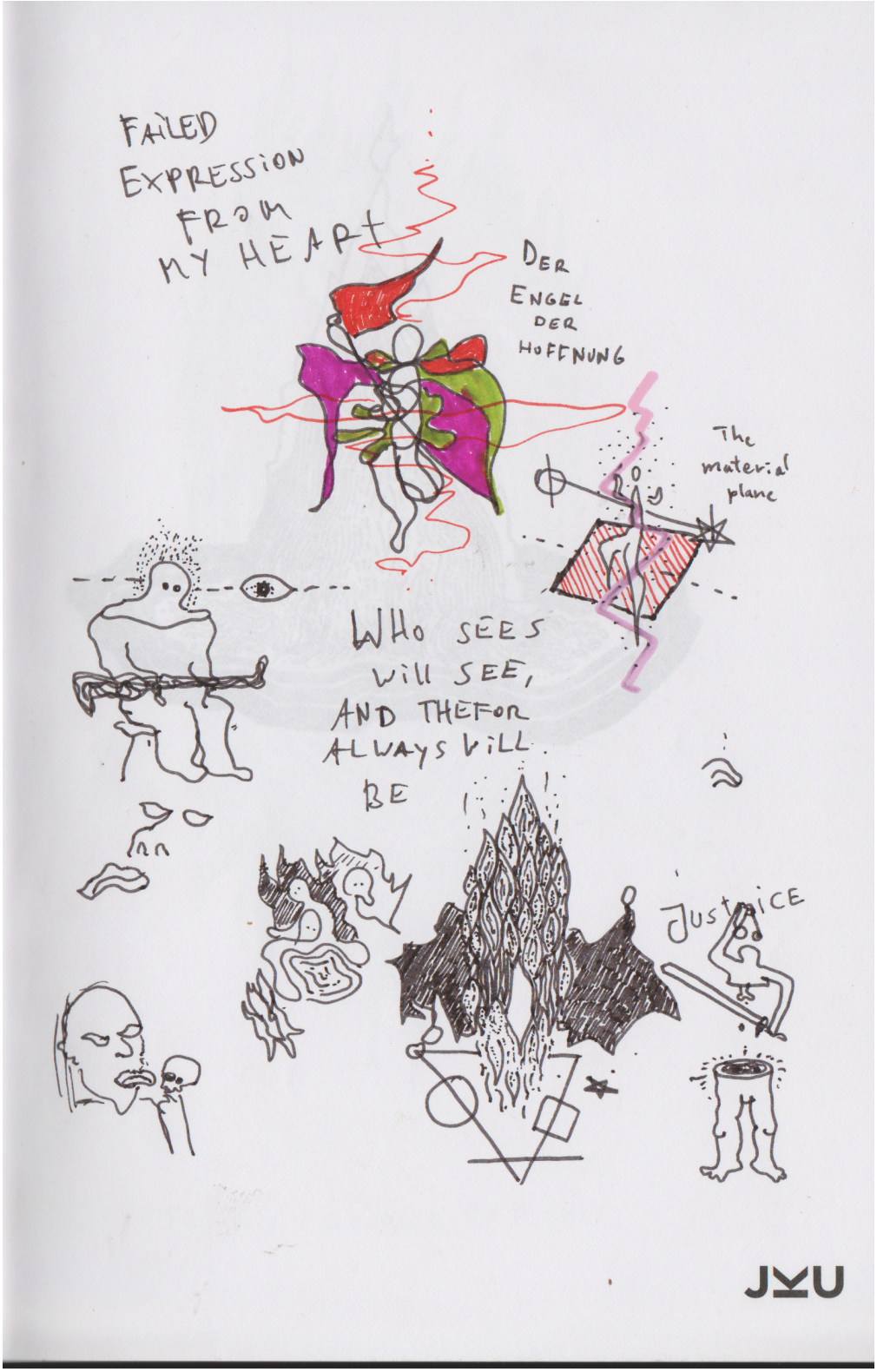

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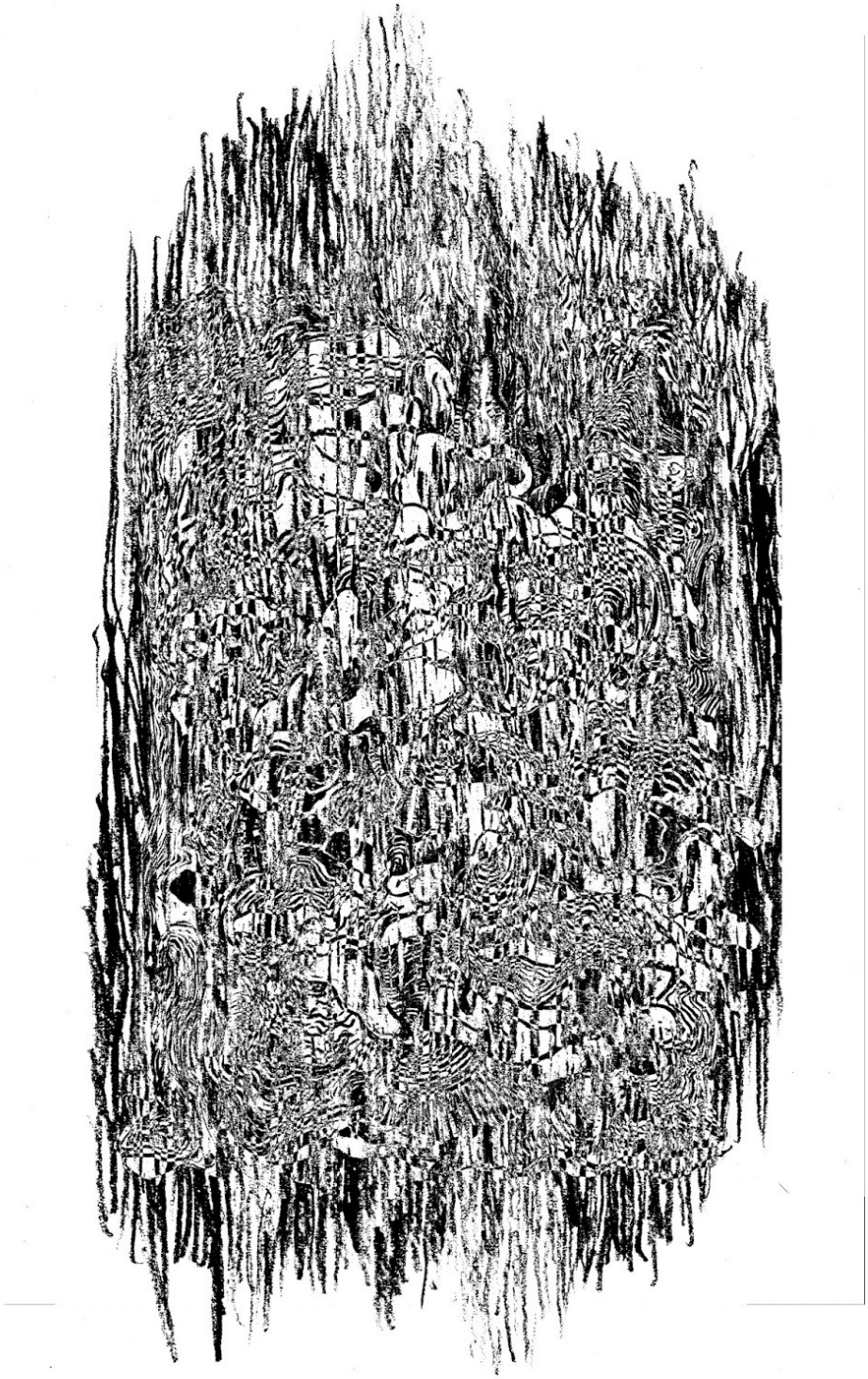

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