Feedback Instruments and Spaces

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Abstract. In my compositional practice, I view feedback as an instrument to address spaces of situated sound inquiry. Such spaces are practically intertwined with, and often mutually defining, the material space in which feedback operates. Feedback instruments as such develop at the intersection of these spaces, becoming mediators between artistic concerns and the material affordances that form and inform them. The first part of this article introduces some of these concepts – instrument, medium, material space – by contextualizing them in the current artistic research discourse, and by situating them in selected examples of historical and contemporary feedback-based productions. In the second part I make use of these ideas to illustrate some of my recent works, focusing in particular on the productive intersections between notions of instruments, media, and spaces in feedback practice.

Keywords: feedback experimentation, electroacoustic instruments, collaborative composition.

Medium / Mediation

In the arts of sound, feedback is a practice of mediation: feedback is always situated in, and *lives* through, a specific medium. Larsen tones, for example, arise from the amplified resonances of sound waves propagating through the medium of air. In a vacuum chamber, feedback cannot occur because there is no air for the sound waves to travel through. In the absence of its medium, feedback dies. From this perspective, the relationship between feedback and the medium it lives in comes close to the notion of a living organism. In the biological sciences, the «medium – or milieu or environment – is the material space in which the organism lives, which keeps it going and through which it keeps going»[1]. Similarly, feedback is always coupled to a medium, an environment, a material space that sustains it. This material space is often composed of different subtrates. If we take a closer look at the Larsen effect, for example, the sonic qualities of the resulting howl are determined not only by the compression and rarefaction of air molecules, but also by the resonance frequencies in the microphone, amplifier, and loudspeaker, the acoustics of the room, the directional patterns of the microphone and loudspeaker, the distance between them, and the phase relationship between their diaphragms. In feedback practice, the material space is a milieu in which sound is mediated and remediated through a situated network of media.

In the arts of sound, feedback is a practice of mediation, in a double sense. For the sound artist, feedback can become an investigative instrument for making sense of the complex material spaces in which it situates. From this perspective, feedback is an instrument in the sense of a medium or mediator: it mediates between the artist and the

[1] Rheinberger, 2016, pp. 161-162.

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material space which is under artistic investigation. It can act as an amplifier, making the aesthetic affordances of a particular material space visible, tangible, or audible. It allows to zoom into that space, acting as a sort of sonic microscope. Through the lens of feedback, material spaces become spaces of aesthetic inquiry.

I guess my fascination with feedback is precisely related to its dual nature. It *demands* a medium, an environment, a material space that sustains it, and at the same time it allows to investigate that medium, becoming a medium in itself, a mediator, an instrument through which artistic and technical concerns are brought to the surface, are shaped and acquire contours. Feedback is thus the instrument with which I approach material spaces of situated sound inquiry: it mediates between me and a context, a site, or a situation that I want to artistically investigate. It informs about the peculiar affordances of that space, and it forms situated interventions specific to, dependent on, and situated in, that very space, shaping a compositional "research process driven from behind"[2,3].

The following sections present some historical and contemporary examples of feedback-based works in electronic music and sound art[4]. These examples are chosen to frame a certain *experimental* compositional approach and to contextualize an understanding of instrumentality and mediation that expands the general notion of feedback instruments. Particular attention is paid to the productive interferences between ideas of instruments, media, and spaces in feedback practice. This approach is then elaborated through the lens of my astistic practice, drawing in particular on the experiences of: the *sun til threads* project, an experiment in feedback instrument composition; *Klangnetze*, an adaptive audio network for public space; *Observatorium*, a site-specific electroacoustic feedback circuit in San Cesario di Lecce, Italy.

Instrument / Space

My Affairs with Feedback is a short text, featured in the 9th Volume of Resonance Magazine, in which Alvin Lucier[5] writes about some of his feedback-based works. It also includes a retrospective report on the genesis of his piece called *Bird and Dyning Person*. The report is particularly interesting because it hints at how feedback, before being embedded into a musical context – that is, before becoming a *musical* instrument – can take on the role of a mediator, with a generative character that comes close to the role of a *scientific* instrument in a laboratory setting: fostering sudden discoveries and generating unexpected results, opening up spaces of inquiry[6]. The report is set

[2] Dombois, 2019.

[3] Rheinberger 2018, pp. 1-20.

[4] The examples selected are not exhaustive or representative of the rich history of feedback practice. For a comprehensive overview see Sanfilippo and Valle, 2013, p. 12.

[5] Lucier, 2002.

[6] This relates to a view of scientific research as experimental activity. In this specific understanding, research instruments and objects of investigation undergo processes of mutual definition, as Rheinberger

in the Electronic Music Lab of the Wesleyan University. On Thanksgiving Day 1975, "with nothing better to do", Lucier was experimenting with panning the sound of an electronic birdcall between two loudspeakers. The birdcall, actually a Christmas tree ornament, emitted endless repetitions of a downward glissando and a series of repeated chirps. At the same time he was wearing a pair of miniature Sennheiser binaural microphones, trying to produce short time delays by moving his head rapidly back and forth, although he commented that "since that seemed unlikely, perhaps I would discover some other interesting phenomenon".

> At one point, as I was standing in the middle of the room, feedback started to sound. Before I could get to the amplifier and lower the volume control I began hearing phantom images of the birdcall, which seemed to come from inside my head and at the same time to be located in various parts of the room. They were amazing[7].

What he was hearing was heterodyining in the audio range, produced by the interaction between the continuous strands of feedback and the sounds of the birdcall, resulting in phantom shapes of various kinds:

> Whatever these phenomena might be called, including resultant tones, heterodyne components or inter-aural harmonics occurring only in the brain of the listeners, the results are spectacular. Listeners can hear them vividly[8].

After this discovery, Lucier developed a simple setup to bring *Bird and Person Dyning* to the stage. It consists of a birdcall mounted on a microphone stand and positioned in the front middle of the space, flanked by two stereo loudspeakers. The birdcall is not mixed into the sound system. The performer wears binaural microphones, routed through long cables to a mixer with compressors-limiters and amplifiers to the two loudspeakers. The performance revolves entirely around the process of acoustically discovering the performance space through this simple feedback device:

> Before the performance the performer, with the help of the sound technician, searches the spaces for room reconances whose sonic manifestations as feedback, cause heterodyning. The spatial relationships between the binaural microphones and the loudspeakers determine the geographical locations of the phantom birdcalls. Sometimes the results are vivid. At other times, however, the room just outputs a few unwanted resonances. The performer accepts the task of finding the appropriate strands of feedback that create phantom images of the birdcall[9].

points out: "In the development of research technologies, it can often be observed that the formation of an instrument goes hand in hand, indeed is almost intertwined with the process in which an epistemic object takes shape." See Rheinberger, 2008.

7 Lucier, 2002, pp. 24-25.

8 *Ibidem.*

9 *Ibidem.*

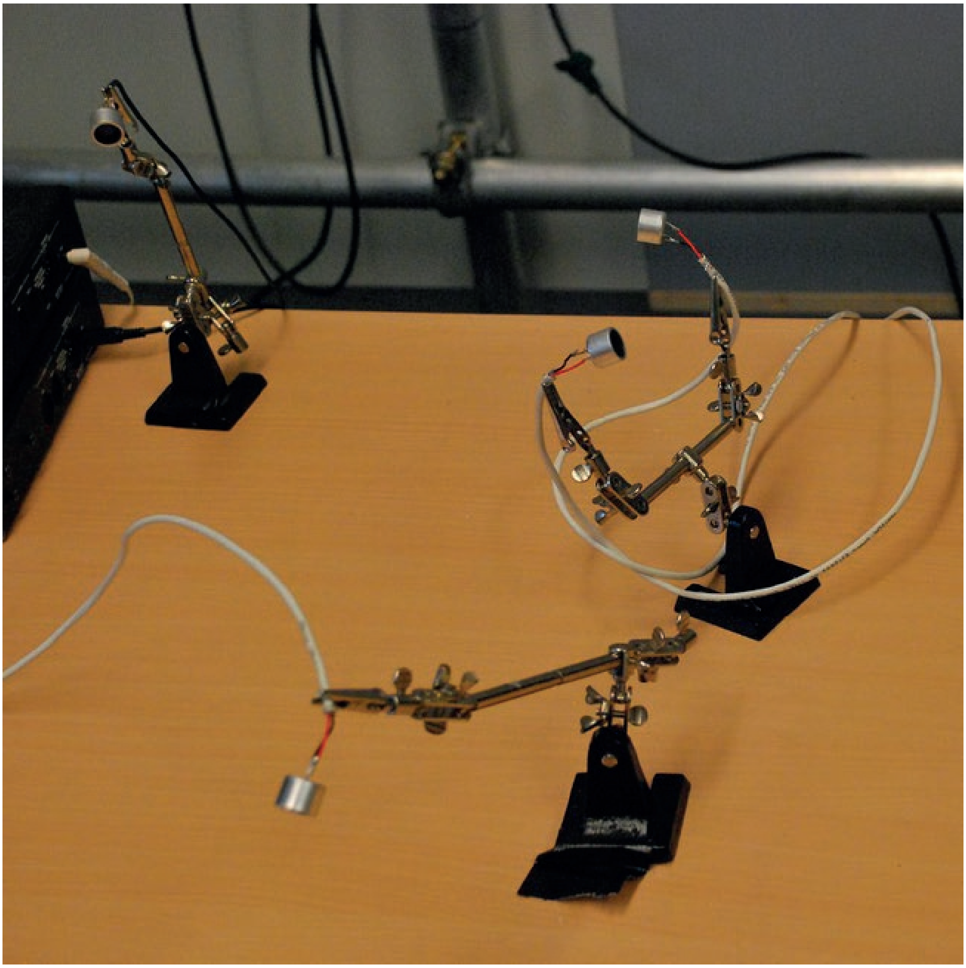

Figure 1. Ultrasound transmitters and receivers in Kuivila's setup for *Listening to the Air*.

A more recent piece that combines feedback with heterodyning, this time in the ultrasound domain, was developed by Ron Kuivila during a residency embedded in the artistic research project *Algorithms that Matter*, hosted 2018-2021 at the Institute for Electronic Music and Acoustics in Graz[10]. The piece, entitled *Listening to the Air*, seeks to expose the shaping influence of air currents on sound waves in the inaudible range. Kuivila assembled a setup of ultrasound transmitters and receivers and connected them in a feedback network of intermodulation (Fig. 1). The setup relies on precise positioning of the ultrasonic units, where audio feedback – similar to an

[10] Algorithms that Matter (Almat) is an artistic research project by Hanns Holger Rutz and David Pirrò. The project Almat ran from 2017 to 2020 within the framework of the Austrian Science Fund (FWF) – PEEK AR 403-GBL – and was funded by the Austrian National Foundation for Research, Technology and Development (FTE) and by the State of Styria. It was hosted by the Institute of Electronic Music and Acoustics (IEM) at the University of Music and Performing Arts Graz. https://almat.iem.at/

ultrasonic microscope – amplifies the interference of air currents – such as the air convection created by a tea light candle – with sound waves in the ultrasonic range. Heterodyning is then applied to transpose signals into the audible range, which are then reproduced through full-range loudspeakers. In this work, too, prior to becoming a musical instrument, feedback is first and foremost a tool for sonic exploration and discovery: it makes audible and accessible the interferences that occur in the otherwise intangible ultrasonic space, and it opens them up to direct, physical manipulation in performance[11].

Both *Bird and Dyning Person* and *Listening to the Air* could be considered outcomes of a compositional approach rooted in an experimental spirit in which feedback acts as an instrument, in the sense of medium or mediator, between the sound artist and the material space under investigation. Feedback lives in, and through, that very material space, and mediates the perception of that space by informing aesthetic choices and shaping further developments. As Nicholas Collins has noted, «feedback reveales links between electronics and acoustics, between circuitry and instruments, between structure and sound»[12].

Electroacoustic Feedback / Acoustic Space

Like Kuvila, Nicolas Collins was a student at Weslyan University in the mid-70s, where Lucier was teaching. It was around this time that he began to work with feedback. In a recent article published on Resonance Journal[13], Collins reconstructs the genesis of his famous feedback work *Pea Soup*, a piece that creates a site-specific "architectural raga" out of a room's resonant frequencies, in which the phrasing is a function of the space reverberation time. The piece stems from the discovery that when a loudspeaker and microphone are connected through a phase shifter, varying the delay (degrees of phase shift) emulates moving the microphone toward and away from the loudspeaker, which in turn causes the feedback to break at different frequencies. Controlling this virtual movement with the loudness of the signal "mimicked a nervous sound engineer jerking a microphone away from the speaker as soon as it starts to feed back". The text provides a few interesting insights. The first one is a hint at how Collins arrived at the setup he would then use for all the *Pea Soup* realizations (Fig. 2).

> Back in Middletown, I adapted my patch to the task of using a similar loudness tracking of feedback to "move" a live microphone, instead of panning Lucier's recordings. Over a period of weeks I whittled away modules until I was left with the simplest of

[11] A recording of *Listening To The Air* is available at https://www.researchcatalogue.net/view/386118/431742. Accessed March 15, 2025.

[12] Collins, 2002.

[13] Collins, 2021, pp. 168-181.

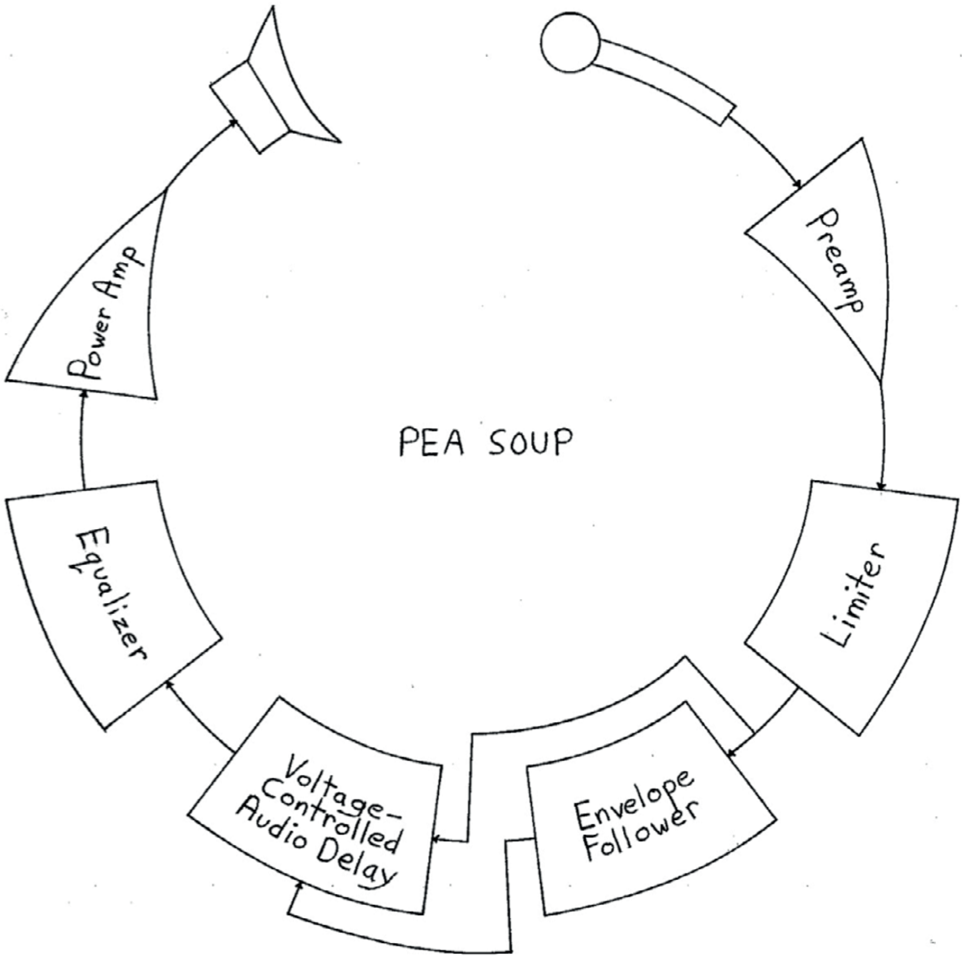

Figure 2. *Pea Soup* original patch diagram (Collins, 2021).

> configurations: microphone > preamplifier > limiter > phase shifter > amplifier > speaker, with optional equalization[14].

The article also highlights how each element in the feedback chain depicted in Fig. 2 affects the overall process of sound remediation. Collins provides insight into the aesthetic decisions that guided the technical development of *Pea Soup*. For example, he stresses how the choice of microphone is a crucial compositional decision in such systems:

> By experimenting with the various microphones in the studio I discovered that omnidirectional mikes produced a much wider, less shrieky range of pitches than the

[14] *Ibidem*.

> more common unidirectional cardioid microphones (even the best cardioid mikes have rather irregular off-axis frequency response, which I suspect affects their feedback characteristics)[15].

Different limiters also greatly affect the sound qualities of the feedback chain. He found that the limiter built into the Sony 152SD portable stereo cassette recorder "did a wonderful job of taming feedback's shriek, reducing it to a mellow sine wave".

As a result, *Pea Soup*'s feedback system is highly sensitive to any movement in the performance space.

> Perhaps the most elegant aspect was the responsiveness of the sound itself: one "played" this system not by twiddling knobs or pushing buttons, but by moving or making sounds within field of the feedback. I began to visualize people and objects in a room in terms of their disruption of the flow of sound waves through the space, like blocks placed in the water of the wave-tank used in physics experiments[16].

Pea Soup is thus an example of how feedback instruments and their material spaces can get so entangled to the point of becoming indivisible. In *Pea Soup* the performance space is as much an instrument as the electroacoustic chain developed to study its acoustic properties and to make its resonances audible. But what also emerges from the report is that the development of the *Pea Soup* instrument – the specific technical configuration that Collins used in performance – opened up just as many spaces of technical-aesthetic inquiry. This suggests that the composition of a feedback instrument is not a linear process, a problem to be solved with a single solution: developing a feedback instrument is as much about forming as it is about being informed, and the end result, the *work*, is to be found somewhere at this intersection.

Many musicians and sound artists choose room-scale acoustic feedback as a site of aesthetic inquiry. A recent example is the *utrumque* project, which since 2018 combines rooms scale feedback with digital modeling of physical acoustics in a layered approach to site-specificity[17]. *rotoscillombrage* is a concert performance and installation by *utrumque* centered around a moving loudspeaker that rotates at the end of a seven meter long arm, which in turn also rotates (see Fig. 3). The work was premiered in 2024 in the Aktionsraum at the Toni-Areal, Zurich University of the Arts (ZHdK). In *rotoscillombrage*:

> The arm allows for precise spatialization of sounds by moving and rotating the speaker to engage resonances and delay patterns in the performance space. By using microphones and digital signal processing, room-scale acoustic feedback is employed as a synthesis method, charging the slightest variation in the loudspeaker position with the power to change the music completely. Both rotating joints are driven by computer

[15] *Ibidem*.

[16] *Ibidem*.

[17] Elblaus and Eckel, 2020, pp. 69-76.

Figure 3. Rotating arm and loudspeaker in rotoscillombrage by *utrumque*, Aktionsraum, Toni-Areal, ZhdK.

> controlled motors and the movements of the whole construction correspond to features extracted in real-time from the music. As the character of the feedback changes as the speaker moves, the resulting sounds change as a consequence, which in turn changes the audio analysis resulting in a change in the position of the speaker[18].

The original idea was first tested through a computer simulation which, based on a set of binaural impulse response measurements of the Aktionsraum, allowed to listen to different room responses relative to specific arm and loudspeaker rotations with respect to a static microphone, placed on one side of the room. The simulation informed the concrete implementation of the robotic arm, developed by *utrumque* in collaboration with Peter Färber of the Institute for the Computer Music and Sound Technology (ICST), ZHdK.

Rotoscillombrage and *Pea Soup* share some similarities: both works engage with the acoustic phenomena that occur when a sound medium – an electroacoustic transducer – is slightly displaced through the acoustic space in which feedback takes place. In *Pea Soup* the sound medium is a "virtual microphone", whose movement is simulated by a time-variable phase shifter. In *rotoscillombrage* it is a loudspeaker, whose movement was first simulated by digital modeling and then implemented in the form of a seven-meter-long robotic arm in order to achieve the slowest possible movement. In both pieces, feedback is employed as a situated instrument to research acoustic phenomena and their compositional affordances in a specific space: an instrument that operates at the intersection of the *simulated* and the *concrete*, allowing to specifically isolate a single variable of a complex system and to experiment with its manipulation.

Zooming further into feedback instruments and their spaces of simulation, the next section discusses examples of purely digital systems in the computational domain.

[18] Elblaus and Eckel, 2023.

Digital Feedback / Computational Space

The computational space has been defined as the conceptual space that resides temporarily in the magnetic, semiconductor locations during the execution phases of computational processes that deal with the manipulation of computer symbols as numbers (integers, floating point, double precision, etc.), dimensioned arrays, and matrices[19]. Digital feedback–processes that apply recursive operations to computer symbols and signals–can provide an alternative access to this space in the sound domain. A concrete example in this direction is the work by Timothy Schmele, who uses internal feedback as an *investigative device* to highlight peculiarities of the Ambisonics spatialiation format. His work *Spherical Glitch Study* is a composition for one laptop performer and a spherical loudspeaker setup. It consists of only two sound sources that reproduce basic sine tones and manipulates them using spatial means. First, they are rotated at extreme velocities, which evokes spectral splits per dimension and decorrelates the generated harmonics in space. The entire spherical sound scene is then folded onto itself by means of an internal spatial feedback loop. This approach evokes and highlights glitches present in the spatialisation approaches, so that «the medium in which the process is situated becomes audible and comes to the foreground»[20]. Feedback is thus used as a tool to zoom into the ambisonics computational space and to bring out its concrete implementations as compositional material. Schmele's work is concerned with an introspection of the media in which the Ambisonics format is formulated, and makes of its specific technical, conceptual and functional aspects a central compositional principle.

A similar approach can be taken to zoom into the workings of a particular software, or even to foreground or make audible the ways in which sound processing is concretely performed – calculated – by computers. This could be understood as a form of *site-specific practice*, where the site is the computational space defined by a specific software environment. An example from my own work is the *strip* synthesizer, a digital instrument based on recursive phase modulation in which feedback amplifies the quantization noise of the software it is written in (SuperCollider). *Strip* is built around two infrasound sine oscillators that cross-modulate each other's phase with single-sample feedback. At each new sample, the phase of the two oscillators is computed by adding the current phase of each oscillator to the one sample old output of the two oscillators, as follows:

$$x(t) = cos(wt + Ax(t-1) + By(t-1))$$

$$y(t) = cos(wt + Cx(t-1) + Dy(t-1))$$

[19] Ahamed, 2014, pp. 171-189, and 2017, pp. 431-450.

[20] Schmele, 2024.

In phase modulation (PM) synthesis *A*, *B*, *C* and *D* are commonly referred to as modulation indices and their value determines the amount of modulation that is applied to the signal. Because the frequency of the two oscillators is well below the human auditory threshold, they remain inaudible without modulation and feedback. In particular, the two oscillators are tuned to a frequency between 0.0002 and 0.00008 Hertz that corresponds to a sine wave with a period between 77 minutes and 3 hours and 28 minutes. Due to the specific implementation of the SinOsc Ugen and to the limitations of floating-point representation, these oscillations cannot be properly computed. The difference between successive samples is too small to be represented, and quantization noise arises from the rounding errors, introducing noticeable distortion and aliasing. In *strip*, feedback amplifies these digital artifacts, turning numerical overruns and underruns into generative seeds for the feedback system itself. As such, the *strip* synthesizer could be understood as an example of a system- and software-specific feedback instrument, which centers around the specific way the SinOsc Ugen deals with numbers it cannot represent. Instead of relying on traditional noise generators, noise is found through a recursive amplification of the numerical indeterminacies produced around these oscillatory liminal regions. The *strip* synthesizer was originally developed as a closed digital feedback system, but it now also includes the possibility of routing external signals (microphone / line inputs), in order to be able to play and improvise with other musicians[21].

A similar approach to digital feedback instrument composition can be heard, for instance, in *Fantasia On A Single Number* by Stelios Manousakis. The piece is performed by playing an «instrument based on digital feedback, set in motion by one single number. No other sound sources are used but real-time manipulation of the number's path within a synthetic space»[22]. Of particular relevance is the work of Dario Sanfilippo, who has worked extensively on closed-loop digital feedback systems, applying concepts and techniques from general systems theory to digital signal processing[23]. His generative piece *Constructing Realities*:

> Shows the performance as a closed self-oscillating system that is triggered by a Dirac impulse, and the entire piece is the complex system's response to a single impulse without human intervention. This closed-system configuration results in a development that spontaneously decays to silence after about 26 minutes, determining the end of the piece[24].

[21] In the 7th episode of the *End of Text* recording series, *strip* was coupled with two hybrid systems (SuperCollider and modular synth) by Luc Döbereiner and Ludvig Elblaus https://endoftext.org/. Excerpts from *strip*, in the form of quantization noise studies, are collected here: https://www.researchcatalogue.net/view/2944513/2944514. Accessed March 15, 2025.

[22] https://modularbrains.net/portfolio/fantasia-on-a-single-number/. Accessed March 15, 2025.

[23] Sanfilippo, 2020.

[24] Sanfilippo, 2021.

Sanfilippo builds on Agostino Di Scipio's research in *ecosystemic digital signal processing*[25]. In particular, Di Scipio theorized a holistic approach to live-electronic music composition that transcends traditional paradigms of "interaction" in computer music and live electronics, framing it rather as a relational property established between sound materials. As Meric and Solomon note in Di Scipio's *Audible Ecosystems* series:

> The emergence of sound structures is possible because of the fact that the composer develops systems (in the sense of cybernetics) close to living systems, which are characterized by their capacity for auto-organization. To make sure that the system is auto-organized, Di Scipio uses "circular causality", which extends the idea of feedback[26].

In *Background Noise Study*, part of the *Audible Ecosystems* series, the delayed background noise of the room is recursively amplified, «likely to be perceived, at the beginning of the performance, as the hiss of a somewhat cheap, low-fi electroacoustic setup. Listeners are deliberately presented with something usually foreign to all music, the trace of the equipment amplifying the ambience sound, magnifying something we usually do not pay attention to»[27]. Here, again, feedback zooms into the media in which sound takes place, and the noise found through recursive amplification is employed as a generative seed that paves the way for the emergence of high-level sonic structures.

Feedback, as contextualized so far, can thus be understood as an instrument in a dual sense: as a vehicle for exploring specific spaces, materials, or phenomena, and as a compositional technique for placing them at the center of sound works. However, it is also possible to reverse this relationship and consider feedback instruments as sites of inquiry in themselves, encouraging reflection on the idiosyncrasies of specific compositional practices. This approach underlies the genesis of the *sun til threads* project presented in the next section.

sun til threads*: a Collaborative Experiment in Feedback Instrument Composition*

The compositional research I am conducting with sound artist and composer Ludvig Elblaus as *sun til threads* centers around the development of shared electroacoustic feedback instruments for live electronic music performance. The project orginates from an experiment in feedback instrument composition, conducted in the framework of the artistic research project *Simultaneous Arrivals* (*simularr*)[28], of which Elblaus was guest artist in April-May 2023. The experiment, rooted in the practice of

[25] Di Scipio, 2003, pp. 269-277.

[26] Meric and Solomos, 2014, pp. 4-17.

[27] Di Scipio, 2011, pp. 97-108.

[28] *simularr* investigates how different types of spaces – thought spaces, aesthetic spaces, architectural spaces – and their corresponding modes of spatiality interact and interfere in artistic collaborations. https://simularr.net.

digital liuthery, questioned whether the process of developing a feedback instrument could be collaboratively designed to interfere and interact with one's own compositional preferences, fostering reflections that challenge established habits and techniques. It consisted of (1) a preparatory stage, where we formulated a rigid set of rules that informed (2) a development phase, in which we independently developed a set of new digital feedback instruments. This was then followed by (3) a period of rehearsal and music production in which we played and adjusted the instruments together in a pre-selected location.

Preparation

Prior to the development phase, we formulated a set of rules for the design of two new feedback instruments, with the purpose of limiting and constraining some of the compositional techniques we are accustomed to. Both Elblaus and I have a long practice of writing digital instruments in the SuperCollider language. The disposition we defined constrained the way an instrument could be conceived, imposing a strict digital scaffolding that reduced both the techniques that could be used and the number of operations that could be expressed. It turned instrument design into an experimental process in which we were forced to approach problems differently and to rethink our own habits, techniques, and preferences[29].

The set of rules defined the instruments in terms of code, control interfaces, and acoustic relationship to the performance space, as follows[30]:

- Code
  - Each SuperCollider instrument may not exceed 80 lines of code, and no line may exceed 80 characters.
  - There are no limitations to what characters are put into the 80x80 grid of characters that make up each instrument.
  - The instrument code cannot call any class or function not available in vanilla SuperCollider.
- Controls
  - The instrument can be controlled using a maximum of 16 rotary encoders.
  - Each controlling encoder may only control levels of audio rate signals in the instrument.
  - The controls are connected with the instrument Synth through the audio buffers 100-116.

[29] As a practical example, when developing feedback instruments I often make use of external plug-ins (UGens I developed that extend the SuperCollider core), while Elblaus relies on a large set of compositional tools, in the form of SuperCollider abstraction, which are part of a large compositional system he built over years. Limiting the development phase to vanilla SuperCollider excluded the usage of both external UGens and libraries.

[30] The code, produced within the project *simularr* and licensed under the GNU Affero General Public License v3+, is available here: https://codeberg.org/simularr/808016. Accessed March 15, 2025.

- Input / Output
  – Each instrument has only one input (microphone).
  – Each instrument has only one output (loudspeaker).

Development: Feedback Node Ring

Throughout the development phase, we regularly confronted each other, reporting on progress and compositional strategies for approaching the constraints of the experiment. Elblaus formulated a rather compact but expressive Digital Signal Processing structure based on a circular digital feedback network of twelve nodes. Each node in the network consists of a simple DSP process with one input and one output. The output of each node is then routed to the input of four other nodes within the circular structure. Two routing paths are fixed: each node always feeds its output back to its input and to the input of its diametrically opposite node. In addition, two other paths route the output signal clockwise and counterclockwise around the circumference. These two routing paths can be parameterized to achieve different feedback structures by defining individual routing rules for clockwise and counterclockwise feedback (Fig. 4). Modifying the feedback structure of the network alters the temporal relationships between DSP processes, resulting in different patterns and long-term oscillations with a rich sonic character ranging from drone-like textures to short melodic phrases. These can be monitored by specifying a listening point along the circumference, which is then output to a loudspeaker. A microphone signal is also summed to the input of each node, completing the setup and allowing to acoustically couple the digital feedback space with a concrete physical space.

What is distinctive about Elblaus' approach is that his feedback instrument relies on an idea of spatiality that makes the relative displacements of the nodes along the circumference, as well as the distances between them, a central generative principle. The notion of distance is crucial here in constructing different structures, and achieving different patterns and textures. In fact, the ring structure in Elblaus' instrument is reminiscent of some of the loudspeaker configurations sometimes found in feedback performances. One example is Christopher Burns' realization of *Electronic Music for Piano*[31] by John Cage (Burns 2004). Burns implemented a system based on a network of eight delay lines in a bi-directional circular audio

[31] Another realization of this work by Cage, recorded by Di Scipio and Ciro Longobardi in 2011, is available on Stradivarius. See Longobardi and Di Scipio, 2012. Di Scipio's electro-acoustic setup greatly differs from that of Burns. From the liner notes of the work: "The sound transformations […] are fed by four piezo-electric discs set in direct contact with woodenand metal surfaces of the piano. Due to these very cheap and low-quality analog tranducers (instead of professional microphones), here the piano sound often takes on rather unusual timbre colors. The goal was a mix of creative amplification and selective equalization of the piano sound; the (welcomed) side-effect was a kind of technically and rather lo-fi timbral connotation […] The sound resulting from the signal processing is heard through two loudspeakers, placed beneath the piano. Therefore, the terminals of the electroacustic chain (piezos and speakers) are rather close among them, the body of the piano acting as an interface between the input and the output terminals."

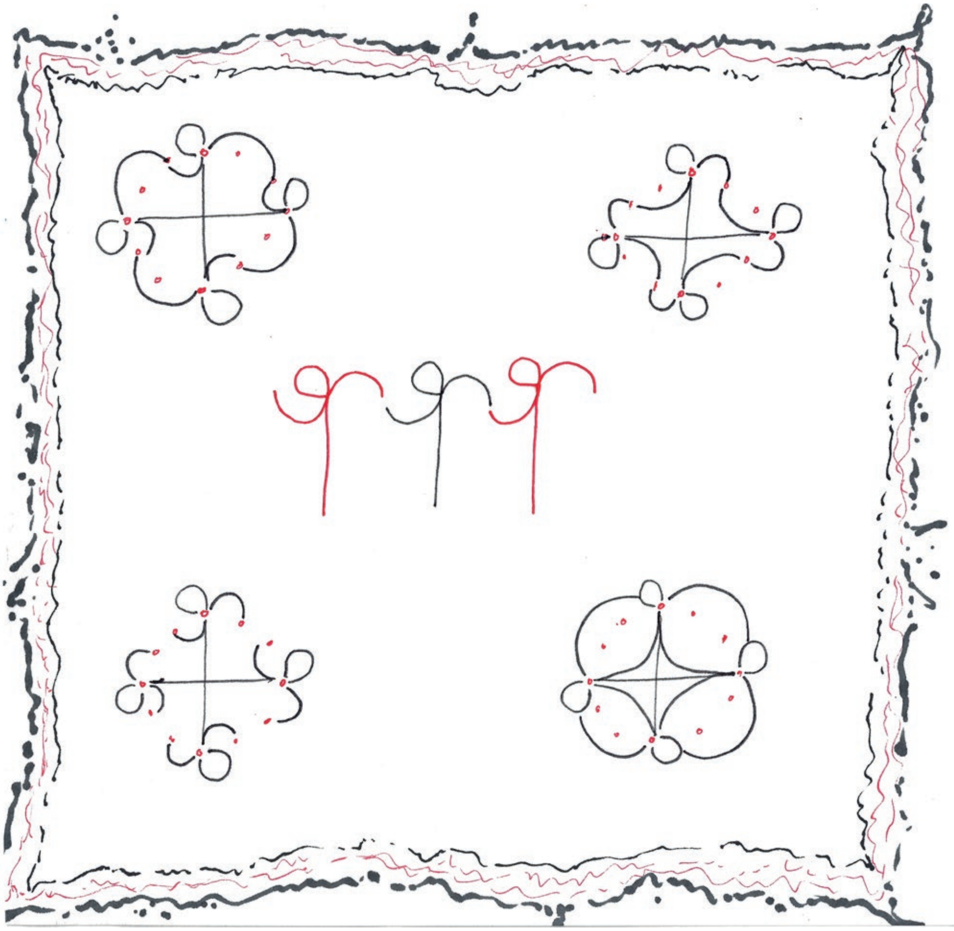

Figure 4. Four node rings with different feedback structures. Nodes are drawn in red, clockwise (CW) and counterclockwise (CCW) routings in black. Top left: 1 CCW, 2 CW. Top right: 2 CCW, 1 CW. Bottom left: 1 CCW, 1 CW. Bottom right: 3 CCW, 3 CW. For visual clarity, only the routing of four nodes is displayed. Original drawing: Ludvig Elblaus 2023.

feedback configuration. Two microphones are connected to two of the eight delay lines, feeding the network with the sound from the piano, and each node's output is connected to a loudspeaker (Fig. 5).

Intuitively, although conceptually similar, a feebdack ring structure in the acoustic space radically differs from its implementation in the digital space. In the acoustic space, it is practically impossible to isolate the outputs of the nodes from the rest of the system: in the configuration shown in Figure 5, the two microphones will pick up all the loudspeakers at once, mediated by the room acoustics. Elblaus's system, on the other hand, makes it possible to selectively isolate, and experiment with, single node-to-node relationships, constructing a virtual space that allows to engage with some properties of feedback that can only be explored in the digital domain.

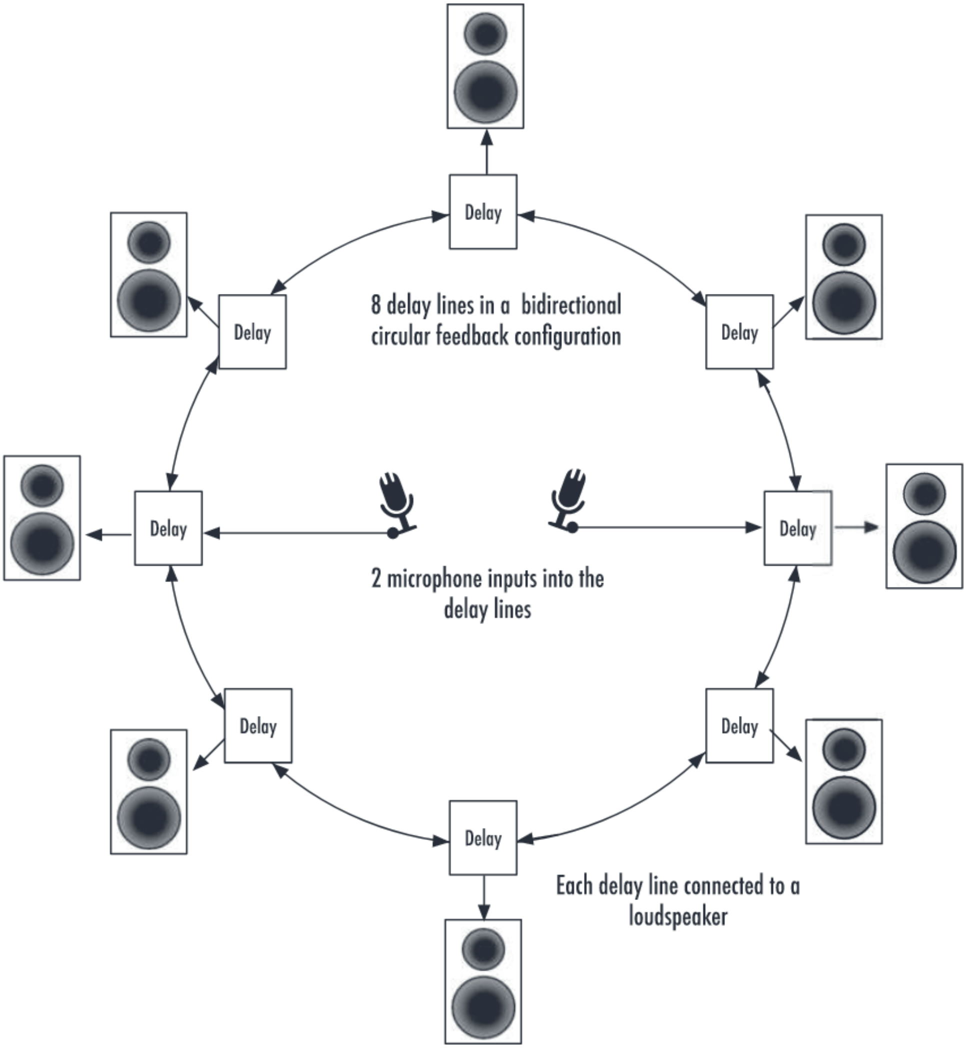

Figure 5. Burn's setup for Cage's Electronic Music for Piano (Sanfilippo and Valle, 2013).

The temporal qualities of the patterns and textures emerging out of the node ring, combined with its high sensitivity to the parametrization of its geometries, demanded a deeper, joint experimentation: we both adopted the node ring as a common scaffold to continue the development phase. I branched off from Elblaus' experiment by writing specific DSP processes that would explore the temporal qualities of the ring. By the end of this phase, I had a total of twelve instruments based on the node ring, and Elblaus had a set of four.

Performance / Rehearsals Space

The second stage of the experiment, centered on rehearsals and music production, took place at Hotel Pupik[32] – an old farmhouse, now converted into an art space, in Scheifling, Austria. Here the main shed (see Fig. 6) was chosen as the rehearsal space, primarily for its acoustic characteristics: six equally spaced columns support twelve arched vaults that create a highly reverberant and sonically rich environment. In addition, it has three doors on the west wall (a large central one and two smaller ones on either side) and three large windows on the north and south walls. This special construction means that the shed is in constant acoustic exchange with the outside environment (a rural area located in the region of Styria, Austria). Various types of birdcalls find their way into the room, but church bells and distant train whistles have also been frequent visitors.

We installed two loudspeakers facing two adjacent walls, to take full advantage of the resonances and reverberation of the space. Two microphones were placed asymmetrically, more toward the center of the room (see Fig. 6). These corresponded, respectively, to the outputs and inputs of our two instruments, creating a complex feedback space in which they could interact sonically, mediated by the acoustics of the shed. When playing together, the instruments fed back into each other, sometimes interlocking, sometimes pushing each other into other sonic regions. As a result, one had the feeling of interacting with a third instrumental space that was reminiscent of a "third voice"[33]: neither under the complete control of one performer or the other, but rather emerging from the complex ecosystemic relationships between the performers, the instruments, and the acoustic space.

During the second week of the residency in Schrattenberg, we rehearsed extensively with the two instruments in the shed. We focused in particular on balancing the coupling between the two instruments, constructing the conditions for them to interlock and interfere with each other, and attuning the influence of the space, the instruments, and us as performers on the resulting sonic textures. At the end of the residency, we released two tracks that capture this particular situation. Especially in the second recording, short term interlocking phenomena and interferences are particularly audible, while the first track works on longer time scales. The tracks are released as *sun til threads*[34], which is the name we have been using to perform together ever since.

Coupling

The *sun til threads* project could be conceived as a form of *performance ecosystem* composition[35], a term that has gained momentum in recent years to frame practices

[32] https://hotelpupik.org/. Accessed March 15, 2025.

[33] Peters, 2017, pp. 67-78.

[34] https://suntilthreads.bandcamp.com/album/pupik-dreams. Accessed March 15, 2025.

[35] Waters, 2007.

Figure 6. Left: Pupik's main shed with the double door open (west facade). Right: Microphones and loudspeakers placement (original shed plan by Franziska Hederer).

that "treat performance as a complex dynamical system in which the feedback loops and interpenetrations between performer, instrument, and environment are fully recognized"[36]. Among the musicians related to this ecological approach to performance, the *Machine Milieu* project by Agostino Di Scipio and Dario Sanfilippo is worth mentioning, as it shares some structural similarities – both in terms of setup and performance approach – with the *sun til threads* project. The *Machine Milieu* project «includes two performers with their computer units, microphones, and loudspeakers, to be placed at strategic positions in the performance space» in which «the idea is to consider the human performer, equipment, and performance space as three sites of agency mutually connected in the medium of sound, capable of developing an integral and possibly autonomous performance ecosystem based on site-specific sonic information only»[37]. In the liner notes to their self-titled release, Di Scipio and Sanfilippo describe the complex, situated sonic interactions that take place in performance as follows:

> By influencing (driving, supporting, inhibiting) each other's behaviour, each system also acts back upon itself, but through the other and the local room acoustics. The project […] creates a hybrid assemblage where both perfomers and machines lean on the shared sound environment as a medium of energetic and informational exchange, thus as a source of real-time situated musical behaviour[38].

In an article published in the journal *Array*, building on the concrete practice of the *Machine Milieu* project, they highlight in particular how a reflection on the nature of *ecosystemic agency* might be relevant to further understanding the performance ecologies of similar projects. In particular, they note that «a viable definition of eco-

[36] Waters, 2013.

[37] Di Scipio and Sanfilippo, 2019, pp. 28-43.

[38] Di Scipio and Sanfilippo, 2021.

systemic agency is better delineated by rethinking the notion of interactivity in light of the more encompassing notion of *structural coupling*»[39].

Structural coupling[40] is a concept rooted in general systems theory[41] to define the process by which two or more systems influence each other's structure over time as they interact and maintain a relationship. In collaborative performance systems such as the *Machine Milieu* or the *sun til threads* project, this notion is often fruitful for thinking about the compositional strategies that can bring musical feedback systems into mutual interaction. Feedback practitioners and musicians often draw inspiration from principles of cybernetics and systems theory. The next section describes *Klangnetze*, a collaborative sound art project for public spaces that implements an electroacoustic system conceived around some of the central principles of complex systems.

Klangnetze*: Adaptive Audio Networks for the Public Space*

The project *Klangnetze*, a distributed sound art intervention in the public space, took place simultaneously in five Austrian cities (Eisenerz, Gleisdorf, Leibnitz, Ligist, Spielberg) in the summer of 2022. *Klangnetze* was carried out by myself and David Pirrò, and featured works by sound artists Luc Döbereiner (*The Small Learning*), Veronika Mayer (*Jodel Poliphonie*), Margarethe Maierhofer-Lischka (*Nachtahn*), Hanns Holger Rutz (*Tagfalter*) and Ina Thomann (*Seated In Bells*). The project took the cybernetic concepts of feedback and network as its aesthetic and conceptual starting point to formulate interventions in the public space that would embed ecologically in their acoustic environment, coming into contact with its sonic properties, approaching them and growing together with them.

Background

Klangnetze draws on ideas from the field of complex systems[42] to explore how these can inform the composition of situated sound interventions in the public space. In

[39] Di Scipio and Sanfilippo, 2019, pp. 28-43.

[40] The notion of coupling is found also in physics: in classical mechanics, coupled oscillators are systems in which two or more oscillators (e.g., pendulums, masses on springs) are connected so that their motions are interdependent. Coupling in these systems can result in interesting behaviors like resonance, energy transfer between oscillators, and collective modes of motion. This form of coupling can also be creatively investigated in the sound domain, as seen, for example, in the *Contingency and Synchronization* series of works by Luc Döbereiner and David Pirrò. See Döbereiner and Pirrò, 2023.

[41] Maturana and Varela, 1991.

[42] The study of networks of interacting components with nontrivial behaviors dates back to the 1940s with the advent of modern cybernetics, which initially began as a discipline connecting areas such as mechanical engineering, network theory, cognition and psychology, and evolutionary biology. For a detailed overview of the development of this field of study, as well as musical works implementing complex Adaptive mechanism, see Sanfilippo, 2021.

Figure 7. *Klangnetz* installed in Leibnitz main square. Left: agents 1 and 2, balcony of the town hall. Right: agents 3 and 4, Maibaum. Highlighted in red: solar panels; in pink: loudspeakers; in green: microphones.

complex systems, the concepts of network, interaction, feedback and agents are deeply interconnected. Networks provide the structural framework within which agents interact, and these interactions drive the system dynamics and emergent behaviors. Such interactions are typically modelled as feedback relationships between agents, and among agents and their environment. Complex systems, which are ubiquitous in physics, nature, society, and biology, inspired the construction of a network of sound agents (in German: *Klangnetz*) that can interact sonically with its surroundings (Fig. 7). Each *Klangnetze* agent (Fig. 8) consists of a small photovoltaic computer equipped with a MEMS microphone and a compact loudspeaker. When multiple agents are installed in close proximity, they form a sonic topology (Fig. 9) in which they simultaneously listen to each other and to the local soundscape. In June 2022, five *Klangnetze* – each consisting of five agents – were distributed to five cities in Styria (Eisenerz, Gleisdorf, Leibnitz, Ligist, Spielberg) and installed in the public space – as an example, Figure 10 shows one sound network installed in the main square of Gleisdorf. Six sound interventions, composed by the invited artists, rotated every two weeks over the *Klangnetze* system, so that at the end of August each of the them was performed at every location.

Situated Sound Networks

In *Klangnetze*, the acoustic environment – the specific soundscape of each city – is the material space in which the sound agents live and through which they communicate. The *Klangentze* system itself can be seen as a site-adaptive instrument that allows to compose site-specific network topologies, and to experiment with different feedback relationships between the network and the environment. Indeed, the aim of the project was to formulate individual aesthetic positions at the intersection of the *Klangnetze* system and the public space, reflecting on mutual sound interactions to create forms of situated sonic interdependence between site and work. Each sound

Figure 8. Klangnetze agents. Left: prototype, May 2022. Center: first version, July 2022. Right: revised version, October 2022.

artist involved in the project was invited to compose a sound intervention in response to this proposal. The following sections describe three such approaches in more detail.

The Small Learning *by Luc Döbereiner: the Network as Sonic Community*

The Small Learning by Luc Döbereiner interprets the network in terms of a sonic community. The title *The Small Learning* refers to the part *Paragraph 7* of Cornelius Cardew's piece *The Great Learning* (1971), a composition for vocal ensemble that consists of a set of rules for each musician to follow, resulting in a kind of emergent harmony. *The Small Learning* also consists of an ensemble of sound agents, all following the same rules. In this case, there are five algorithmic systems that generate synthesized sounds, record ambient sounds, analyze them, and compare them to the synthesized sounds.

From the author's notes:

> *The Small Learning* aims at the emergence of a sonic community, a form of ecology, that connects algorithmic processes, the sonic environment, and musical ideas. Density, pitch, timbre, and musical development emerge from the interactions of the various processes and agents, their materialities, and the ways in which they represent and transmit one another. The sound-generating agents are chaotic systems that, although very simply constructed, have a large space of possibility. It fascinates me aesthetically to experience and trace this space. Interaction with this system often results in surprising patterns, sudden transitions, and sound structures that change and dissolve. I am interested in how this complexity in the small and quasi-ideal domain of digital sound synthesis, can be connected to the sonic environment, i.e. how algorithmic chaos and the unpredictability of the external environment can encounter each other. This is done through a machine learning process that, in a sense, translates data and sounds into each other, adaptively adjusting sound synthesis to the results of an analysis of the environment[43].

In *The Small Learning* sounds are synthesized in SuperCollider using a feedback wavefolder, a type of distortion device used especially in analog synthesizers. The general operation of a wavefolder can be described as folding – reflecting or inverting – an

[43] Döbereiner, 2022, pp. 95-116.

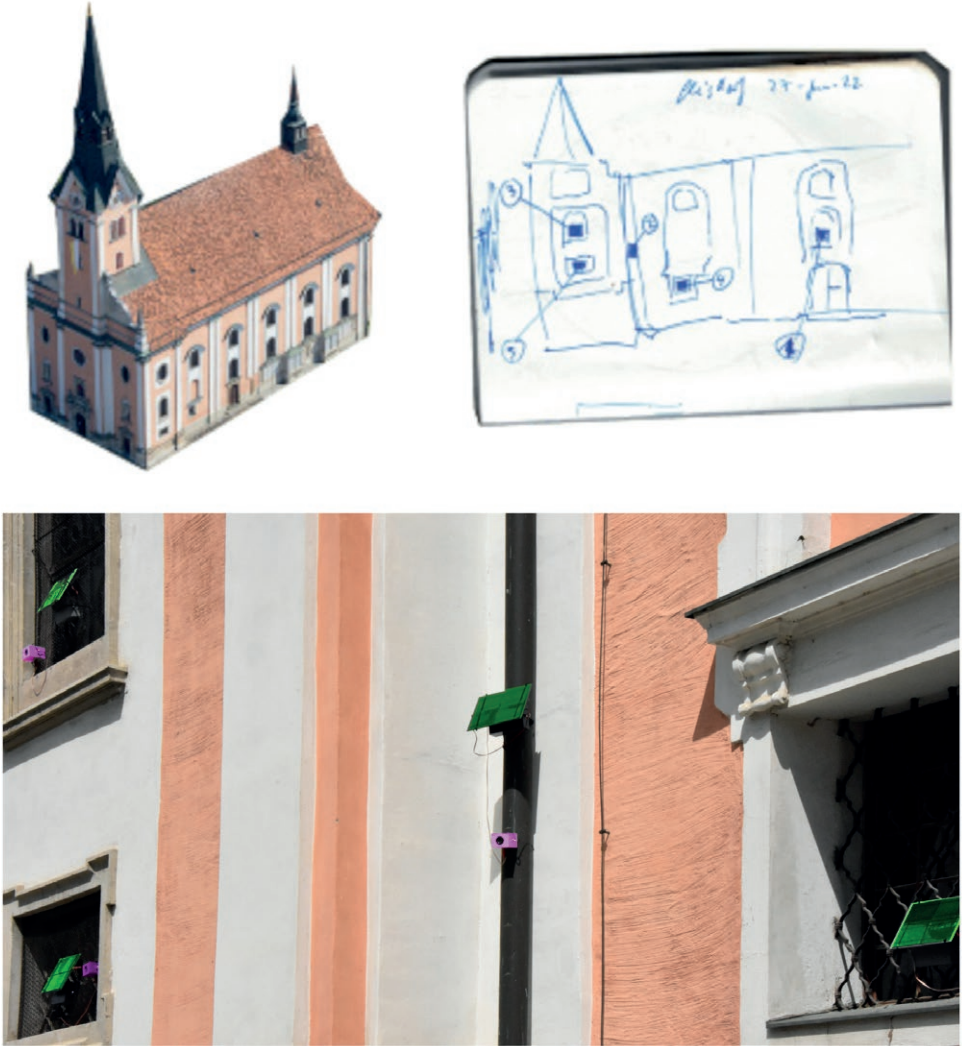

Figure 9. Klangnetz installed on the South facade of St. Laurentius Church in Gleisdorf main square. Top: aerial view and installation plan. Bottom: agents 2, 3, 4 and 5. Highlighted in green: solar panels; in pink: loudspeakers.

input signal as its magnitude exceeds a certain threshold (see Fig. 10, left). In addition, the wave can be shifted, resulting in asymmetric folding (see Fig. 10, right).

Döbereiner points out that:

> Wavefolders become especially interesting in feedback systems, because they can thus form an essential part of chaotic systems as a parameterized nonlinear function. Feedback wavefolders can produce both periodic and chaotic timbral states. The system

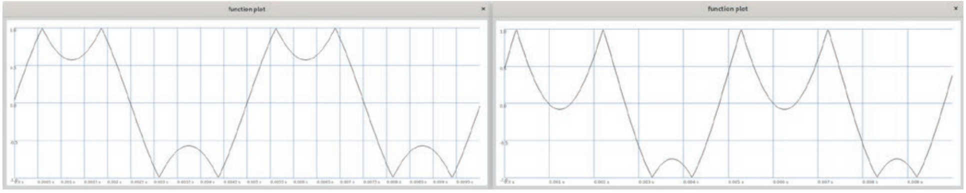

Figure 10. Left: A sine wave folded at amplitude 0.7. Right: Asymmetric folding (Döbereiner, 2022).

used here, while very simple in its components (the feedback input wave is folded at certain thresholds), exhibits very diverse behavior that is difficult to understand[44].

Each of the five agents generates sounds using a feedback wave folder, alternating between sound generation and silence. During their periods of silence, they analyze both their own sounds and the ambient sounds picked up by the microphone. This alternating pattern of playing and pausing directs the analysis inward (self-generated sounds) and outward (environmental sounds), respectively. The analysis yields Mel-frequency Cepstral Coefficients (MFCCs), represented by 13 numbers that capture essential properties of the frequency spectrum at a given moment.

After each iteration, the agents evaluate how closely their generated sounds match the environmental sounds – recorded and analyzed during their last pause – by comparing their respective MFCCs through a k-nearest neighbor (kNN) machine learning algorithm. New parameters are then generated based on a calculation of the distances between the analysis data. Using this algorithm, the agents aim to produce sounds that approximate the sounds of the environment, which includes the sounds of other agents. In the process, they also learn to generate more accurate parameter settings for specific timbres by interpreting their own chaotic behavior.

The agents' adaptation varies with their proximity to the surrounding sounds: the further away they are, the more erratically they explore different possibilities. As they become better adapted, their curiosity diminishes, leading to the production of longer sounds. Rhythmic structures, musical density, and variability emerge from this adaptation process. Throughout, the agents listen to each other and to external environmental sounds, collect data, and strive to adapt, forming a sonic community with each other and their environment.

Tagfalter *by Hanns Holger Rutz: the Public Space as Environment for Sound Communication*

Hanns Holger Rutz approached the network from a different perspective. He composed sound processes inspired by the way living organisms interact and communicate with their environment. In particular, he draws inspiration from the world of insects:

[44] Döbereiner, 2022, pp. 95-116.

> Tagfalter is German for a day-active butterfly (where Nachtfalter would be the night-active moth). Falten is not only 'to fold', as in the flapping of the butterfly's wings, but also the technical term for 'convolution', a digital signal process that is applied repeatedly in the piece. Each of the five nodes enacts a cycle of different modes, usually following the order of 'crypsis', 'detect-space', 'space-timbre', and 'accelerate', interspersed with random occurrences of 'silence' and 'joy'[45].

As shown in Fig. 11, a state machine cycles through the five modes. The *detect-space* mode is particularly interesting: it is the stage in which an agent gathers spatial information about its environment. *Detect-space* emits a series of sweeps: chirps lasting a few seconds, moving from lower to higher frequencies. By observing the echoes of this sound, the agent generates a geometric image of the physical space around it, translated into distances of reflecting surfaces. This image then informs the parameters of all the other modes, most perceptible in the *space-timbre*, which translates these distances into frequencies, creating an internally modulated harmonic or inharmonic sphere. When multiple agents happen to be in the *space-timbre* mode at the same time, one can easily notice the different harmonic spheres obtained from the individual locations of the agents.

Agents also sonically communicate their intention to start an acoustic scan of their environment, so that all other agents remain silent during this operation. This sound signal is also inspired by the way in which living organisms communicate with each other:

> The nodes are meant to communicate among each other using a simple technique called frequency-keying. A pair of frequencies understood by all nodes is used by a node to inform the others that it is about to run its space detection, and to communicate its identity (another pair of frequencies) resulting from the detected space. Then using these individual frequencies, sometimes bursts of joy can be heard, as a similar sounding communication signal, but at these distinct frequencies. If another node notices this, it will reply with its own burst[46].

Trópos*: Soundscape-Modulated Sound Synthesis*

I also composed a sound intervention called *Trópos*, based on the *strip* synthesizer previously described. A central idea in *Trópos* is to work with sounds that might be confused with those already present in the public space. A process of mimesis is synthesized in real time, and the surrounding soundscape directly modulates this process. Each sound that reaches the microphone is embedded in the synthesis program, and sonic and temporal qualities emerge that are specific to the place – and moment – in

[45] Rutz, 2022.

[46] *Ibidem*.

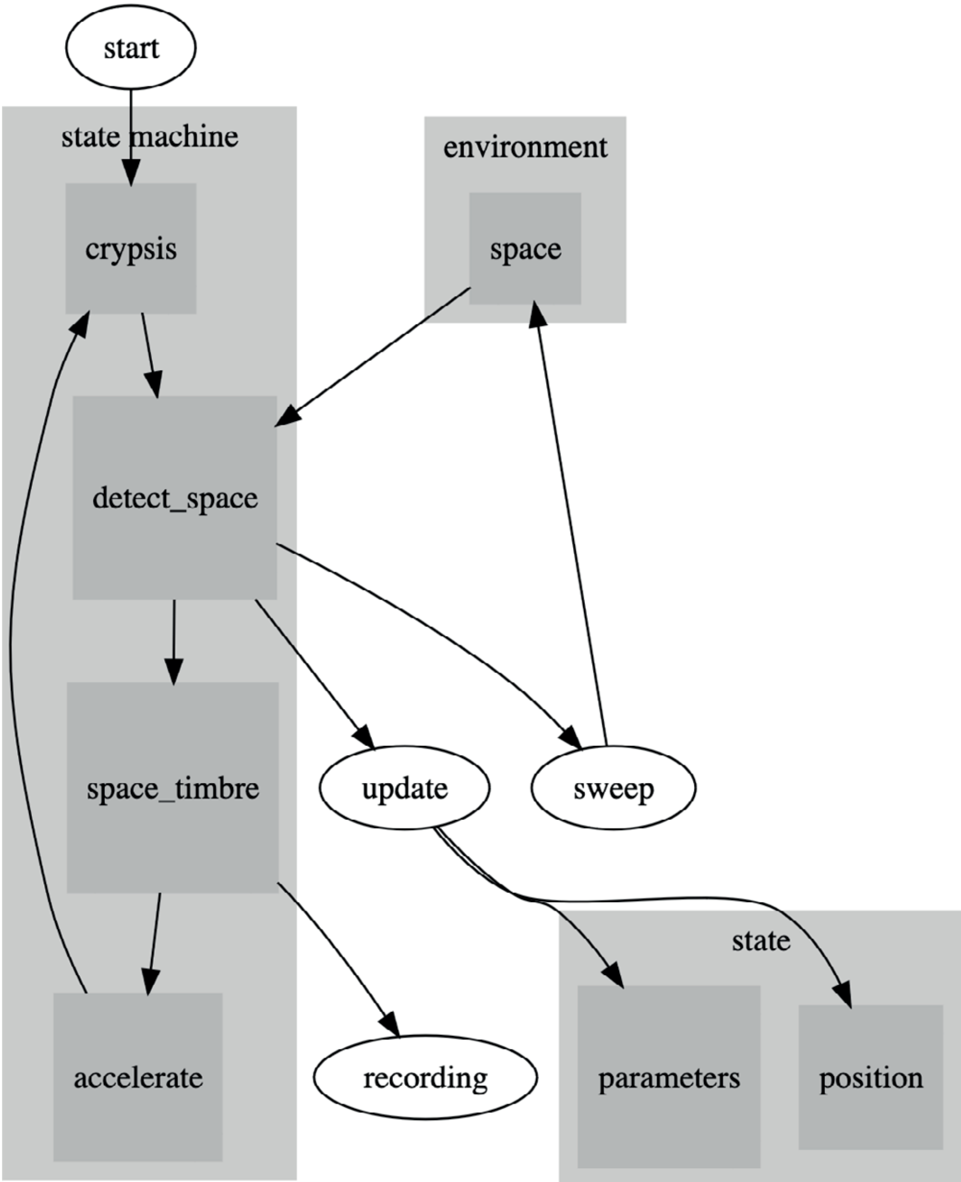

Figure 11. *Tagfalter* state machine. Original drawing: Hanns Holger Rutz (Rutz, 2022a).

which the synthesis takes place. The work is loosely inspired by the biological phenomenon of tropism that indicates growth or turning movement of an organism, usually a plant, in response to an environmental stimulus. Tropisms occur in three sequential steps. First, there is a sensation to a stimulus. Next, signal transduction occurs. Finally, the directional growth response occurs.

> Borrowing this metaphore, I considered the acoustic environment as the source of acoustic stimuli. These are (1) sensed through the built-in microphone and (2) transduced into filtered amplitude values. These values then (3) provoke deviations in a generative sound process, which adapts by modifying its timbral and rythmical qualities according to such acoustic stimuli. This mechanism creates an ever-growing, real-time process of acoustic adaptation in which sound processes concretely take shape from their environment, generating a lively sound situation in which the work is in a direct aesthetic interdependence with the place in which it is installed[47].

Trópos is described in detail in an article that is part of the xCoAx 2023 proceedings[48].

Documentation and Resources

Audio recordings of the six interventions are available on the *Klangnetze* website[49], which also offers an overview of the entire project and a documentation video (in German). The *Klangnetze* hardware is documented in a dedicated instructable[50] and the software is available in the *Klangetze* online repository[51]. The diversity of interpretations and approaches in the project testifies to the generative potential of approaching an electroacoustic system, and the ideas specific to its development, as an instrument for exploring the liminal region between an aesthetic proposition and the concrete space in which it takes shape.

A similar compositional approach was taken in *Observatorium*, an electroacoustic feedback circuit described in the next section. A key difference, however, is that the *Observatorium* feedback system was developed in situ, and the specific acoustic characteristics of its site are central compositional elements of the work.

Observatorium*: a Site-Specific Electroacoustic Feedback Circuit*

Observatorium is a site-specific sound intervention that applies general electroacoustic feedback principles to frame listening as an act of observation, and to draw attention to the productive interferences between observer and observed. In particular, it creates a contrast between the individual listening space and the collective listening space, making the friction between the two a central compositional element of the work. It was developed during the *simularr* artistic research residency at Palazzo Russo, San Cesario di Lecce, Italy, April 2024, and it consists of a distributed electroacoustic

47 Pozzi, 2022b.

48 Pozzi, 2023, pp. 378-382.

49 Pirrò et al., 2022a.

50 Pozzi, 2022a.

51 Pirrò et al. 2022b.

Figure 12. View of the specola from the West rooftop.

feedback circuit, connecting several rooftops and terraces of the historic palace. A plan of the whole circuit is shown in Fig. 18.

The circuit is composed around three main listening points, one of which – the *specola*[52] – is placed on the highest point of the main rooftop, facing East (see Fig. 12). The *specola* is a special listening point in the feedback circuit because it creates a private listening space that can only be occupied by one person at a time. Sitting on an old wooden chair, one must carefully move one's head to align one's ears with the two openings at the end of the tubes. This peculiar listening space is built around two old bed ornaments made of brass, which I found in a deposit in the palace. These were turned into two feedback resonators by inserting two lavalier microphones (see l1 and l2 in Fig. 18) inside the cavities at the end of each ornament, and by screwing two transducers (t1, t2) at the opposite end.

Walking towards the center of the rooftop, one encounters the *collettore* (italian for water collector), a large stone basin hosting a PA loduspeaker (p1), an old antenna and a cardioid microphone (m1). The *collettore* is the second listening point (see Fig. 13). A third listening point is the *parapetto*, which coincides with the rampart that limits the palace rooftop (see Fig. 14). Here a second loudspeaker (p2) is placed on the neighbouring roof, next to the wall that limits the two buildings: it is not visible, it can only be heard.

[52] In italian, *specola* means observatory, hill or summit. It is generally a lookout post. It derives its name from the latin *spècere*, verb for "observing" which also originates *speculum*, the mirror (*specchio*, in italian) – literally, the 'instrument for observing'.

Figure 13. Collettore. Left: view from the West rooftop. Right: detail of the old antenna, with microphone inserted in the tube.

Figure 14. Parapetto. Left: stone wall and water pipe. Center: neighbouring rooftop, not accessible. Right: water pipe holding the two bed ornaments, view from the neighbouring rooftop.

One floor below, on a small terrace, two more microphones are installed next to a water pipe (m1) and on the small chimney (c1) for exhausting steam from the boiler that heats the water in Palazzo Russo. These include a cardioid and a contact microphone, respectively, as shown in Fig. 15.

Listening Points

The three listening points have very different acoustic characteristics, offering three distinct perspectives on the relationship between the work and its surroundings, encouraging visitors to engage with various modes of listening. The *parapetto*, situated along the low stone wall that encloses the rooftop, is the point where the soundscape of San Cesario[53] is more present.The *parapetto* is located at the edge of the building, far from any reflective source, and thus achieves a wide open-air acoustic. The loudspeaker l2 is placed *outside* the Palazzo Russo, on the roof of the neighboring building (see Fig. 14). The neighboring roof is several meters below the *parapetto*: from the visitor's perspective, l2 is therefore both visually and acoustically shielded by the stone wall constructions. As a result, its sound is distant and muffled, mixed with the traffic

[53] The soundscape of San Cesario consists of a mixture of rural and urban elements.

Figure 15. Kitchen terrace. Left: microphone positioned next to the water pipe. Right: contact microphone mounted on the chimney connected to the boiler.

and chatter coming from the adjacent street. On the same vertical axis, the water pipe that is installed on top of the stone wall also vibrates. The water pipe runs around the entire perimeter of the roof, and towards the north terrace it is used as a structural element to keep the two bed ornaments in place (see Fig. 14). Being mechanically coupled, when the ornaments are set into vibration by the transducers, the vibration is transmitted all along the water pipe. Due to the curvature of the roof, this becomes especially audible when standing in front of the *parapetto*.

The *collettore*, located in the center of the rooftop, is more isolated from the traffic and chatter of the piazza below. The stone basin creates an acoustic niche with quite strong reflections that color the sound of the loudspeaker l1 with a bathtub-like reverb. At one end, the old antenna leans directly against the loudspeaker, causing it to vibrate at some very low frequencies. A cardioid microphone is inserted at the other end of the antenna, using its 4 meter metal tube as a long and narrow resonator. Due to the special coloration of the stone basin, which stands out acoustically from the surrounding soundscape, the *collettore* favors a more direct listening experience, as opposed to the more nuanced one of the *parapetto*.

The *specola* is the privileged listening point of the *Observatorium*. It is centered around two brass resonators that act as a kind of ear prosthesis: when a visitor sits between them, the surrounding acoustic environment is heavily filtered by the brass tubes, favoring an immersive, contemplative form of listening that focuses on some particular sonic aspects of the San Cesario soundscape. One of these is the wind, an almost ubiquitous element on the rooftops in the small town. The two brass ornaments are positioned at an angle that allows the wind to blow through them, producing whistling and blowing effects that are sometimes reminiscent of more traditional wind instruments. Each of the two ornaments is also modified by inserting a DPA 4060 omnidirectional microphone and a Visaton BS76 transducer at the opposite ends (see Fig. 16). The DPAs are mounted using generic plastic valves from a local hardware store, which have the dual function of holding the microphones in place and blocking sounds coming from the sides. In other words, the valves modifies the directional characteristics of the lavaliers, so that they pick up mostly sounds coming from the listening cavities themselves. In the *specola*, the two lavaliers are in a feedback relationship with the two transducers, meaning that the microphone signals are recursively amplified to the point of producing static Larsen tones. Due to the specific construction of the listening space, when a visitor sits between the two ornaments, the slightest head movement dramatically affects the feedback process itself (see Fig. 17). The head,

Figure 16. Left: DPA 4060 in black plastic valve. Right: Visaton BS76.

and the act of listening itself, essentially becomes a filter that materially affects the sound being heard. The exploration of such tiny movements is also facilitated by the spcecific shape of the cavities of the bed ornaments: various resonance frequencies can be discovered by simply tilting the head back and forth at different angles.

Feedback Circuits

The *specola* is not the only audio feedback loop in *Observatorium*. In fact, there are several of them, both local (for example, the microphone in the antenna feeds back into the loudspeaker in the *collettore*) and distributed all over the roofs and terraces. Based on on-site experimentation, I composed two sets of circuits, as shown in Fig. 19. The two circuits differ mainly in the balance between *local* and *distributed* feedback loops. In circuit B feedback loops take place in contained spaces, over short distances, working mostly with Larsen tones. In circuit A microphones are much farther away from the loudspeakers, turning the feedback relationship into a kind of distributed amplification of the sounds of – and around – the palace, and using its architectural features as resonators. In other words, both circuit A and circuit B explore the building as a walkable, distributed feedback instrument, although they emphasize different acoustic aspects of its construction.

The two feedback circuits are implemented in a SuperCollider patch that allows to crossover between them. In *Observatorium*, the balance between the circuits is directly coupled to a rough analysis of the sounds picked up by the two DPA microphones (see l1 and l2 in Fig. 18), in a double inverse relationship which combines both negative and positive feedback principles. In particular, the patch calculates the spectral centroid of the signals coming from the two lavaliers mounted in the *specola*. When

Figure 17. Specola listening space.

the spectral centroid moves towards the high register, the connections in circuit A are amplified, while those in circuit B are suppressed. A darker spectrum will have the opposite effect, amplifying circuit B and suppressing circuit A. This creates a situation where the two circuits are in a constant crossover relationship, that depends on the precise conditions which are found in the listening space of the *specola*. Consequently, when one sits in the *specola* and listens between the two bed ornaments, the very act of listening directly recomposes the current feedback circuit. In other words, the visitor's head itself acts as a concrete low-pass filter between the two lavalier microphones, and the slightest movement at this precise location causes dramatic changes both locally (in the audio feedback taking place between the ornaments) and throughout the building. Thus, visitors listen to the sound work and the building, but the sound work also listens to its visitors and adapts to their listening[54].

In *Observatorium*, then, feedback is used, at various levels, as an instrument to investigate spaces of listening. The Palazzo Russo itself, in this context, is both a sounding instrument *and* a listening site. Its network of feedback relationships is constantly reshaped by its visitors, in a hybrid feedback loop in which the two are in a mutual listening relationship. Listening is thus framed not as a passive act, but rather as an active form of attending that is never neutral, inviting to reflect on the relationship between the (listening) self and its (acoustic) environment.

Outlook

This article discussed feedback from a multiplicity of perspectives: as a vehicle for exploring specific spaces, materials, or phenomena; as a compositional technique for placing such spaces, materials and phenomena at the center of sound works; as a structural element that expands to compositional notions of network and adaptivity. Feedback instruments have been framed as mediators between artistic concerns and material contingencies, but also as site of inquiry in themselves. Although feedback

[54] *Observatorium* sound and video recordings are available here: https://www.researchcatalogue.net/view/2908423/2908424. Accessed March 15, 2025.

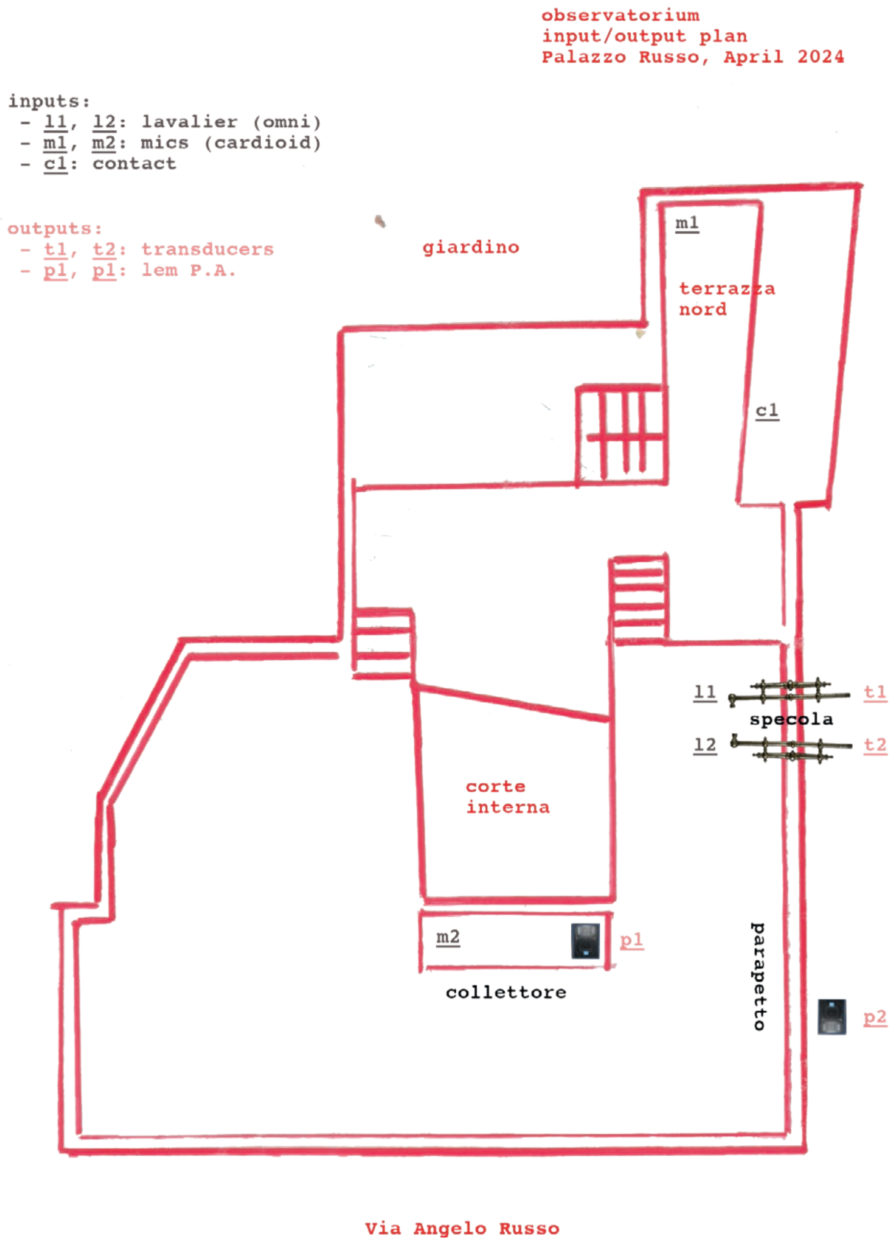

Figure 18. *Observatorium*: input / output plan.

seems to resist a univocal definition – it rather tends to diffract into a variety of fields and applications – all of the approaches presented in this text share a certain experimental spirit, that feedback seems to inspire, animate and sustain. This text is written with the intention of encouraging further reflection on the instruments, media and

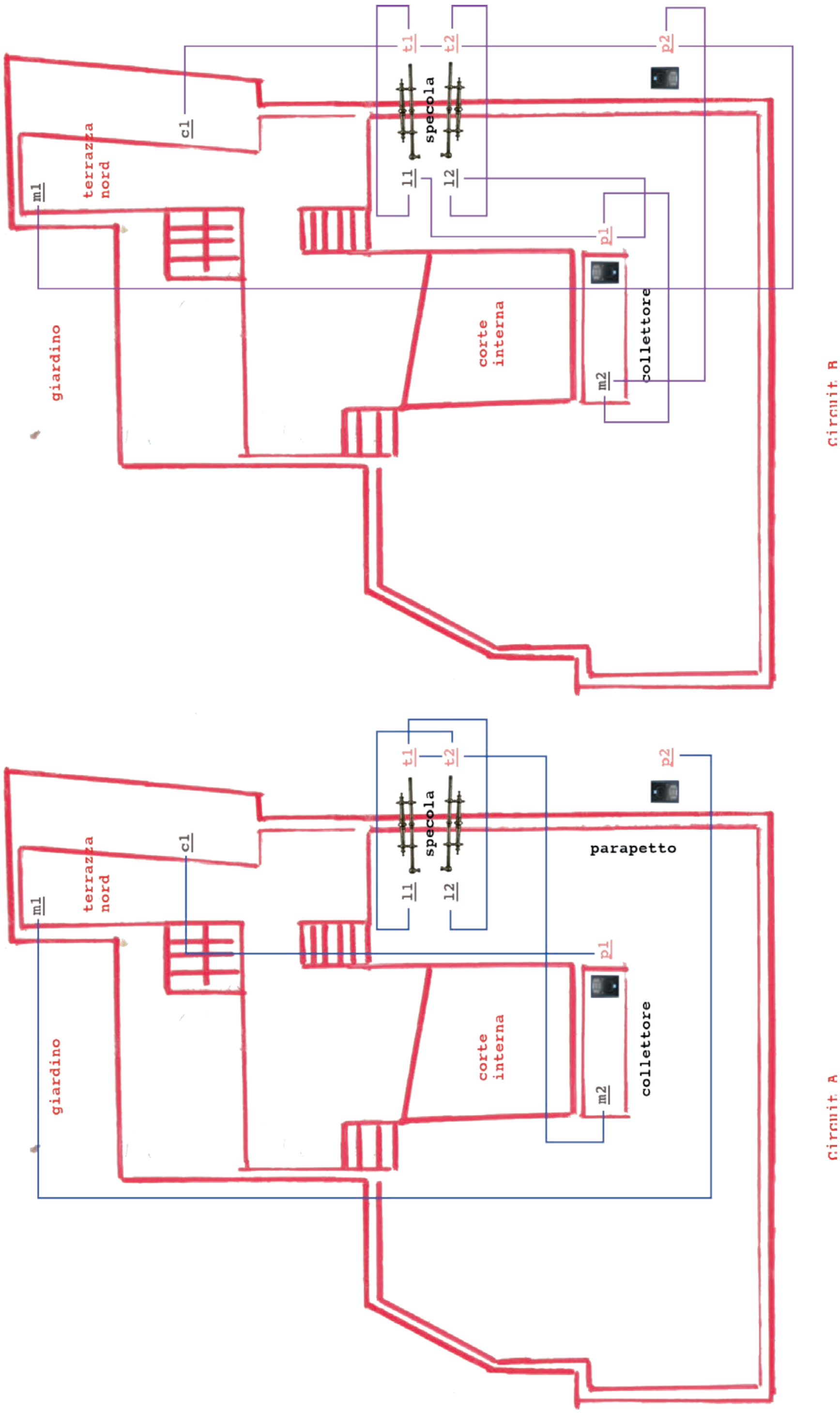

Figure 19. *Observatorium*: feedback circuits A and B.

spaces of feedback experimentation, in the hope that feedback's enigmatic status will nevertheless remain intact.

Acknowledgements

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