Realignment: From Ultrasonic Loudspeakers to a Directional Feedback System

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1. Introduction

At the start of the second semester, my project had reached an impasse. The idea I had pursued in the first semester — an artistic sound installation built around ultrasonic (parametric array) loudspeakers — turned out to be far harder to realize than I had initially assumed. Even before the speakers had been tested, I was warned repeatedly about the high sound pressure levels they require to demodulate in air and become audible, and about the risk these levels pose to hearing. Rather than continue down this path, I decided to step back. A meeting with my advisor marked the start of a realignment of the project.

His central advice was to stop fixating on a single kind of loudspeaker and instead think about the characteristics that distinguish the different loudspeaker types from one another. The project, he suggested, should adopt a comparative approach.

2. The New Idea

Following this advice, a new concept for the installation emerged. Instead of being built around one specific loudspeaker technology, the setup consists of loudspeakers and microphones that can each be aimed independently: every device is mounted on a two-axis (pan and tilt) gimbal. The devices are arranged in front of a wall with sound-reflective properties. A loudspeaker targets a point on the wall at a chosen angle; a microphone aims at the same point. The microphone captures the sound reflected from that point and sends it back into the loudspeaker, closing a feedback loop.

At its core, this can be understood as a directionalized version of Alvin Lucier's ›I am sitting in a room‹ (Lucier 1969). In that piece, Lucier records himself reading a text, plays the recording back into the room through a loudspeaker, re-records it with a microphone, and repeats this process over many generations. The room's size and geometry emphasize certain resonant frequencies and attenuate others — the room acts as a filter — so that with each generation the speech dissolves further, until only the room's natural resonances remain audible. The new installation transfers this principle into a live and spatially directed system. The loop is not closed over an iterative recording process, but continuously: the microphone signal is fed directly

back into the loudspeaker. And because both devices can be aimed, the loop can be confined to a deliberately chosen reflection path, so that the wall — rather than the room as a whole — acts as the filter. Moving the gimbals steers this filter in real time, allowing the spatial arrangement to directly shape the sound of the feedback.

3. Reducing the Concept to a Prototype

For the prototype phase, the concept is reduced to its smallest meaningful unit: one loudspeaker and one microphone, each mounted on a two-axis gimbal. The gimbal sits on a standard microphone stand, connected through a 3/8″ thread adapter. Both devices are directionalized with a horn. Two ESP32 microcontrollers form the control and processing core: they drive the servo motors of the gimbals, handle the sound input and output, and implement the signal processing. The design is deliberately modular — the single pair is a building block that could later be scaled to an arrangement of many loudspeakers and microphones facing a common wall.

Because the horns are manufactured mainly by 3D printing, they are cheap to produce in different geometries. To make a comparison of horn types practical, the horn will be attached to its enclosure with a bayonet mount, a twist-lock coupling that allows the horn to be exchanged within seconds. In this way the horn becomes an experimental variable of the prototype: the same driver can be fitted with horns of different contours — tractrix, exponential, conical or hyperbolic — and their influence on the reflected sound can be compared directly. This mirrors the comparative approach at the level of the individual component.

4. Signal Processing

One design question is deliberately left open at this stage: the role of signal processing in the feedback loop. The concept does not prescribe a particular treatment of the signal; instead, the choice of processing should follow from the direction the installation ultimately takes. Two opposite approaches are conceivable: If the project develops toward a more scientific treatment — where it might, for example, make sense to display measurement data on a screen alongside the installation — the processing

should remain minimal and controlled, probably limited to gain control, so that the behavior of the feedback loop stays reproducible and interpretable. If, on the other hand, the installation leans in an artistic direction, the emphasis shifts to the quality of the sound itself, and a wider range of signal processing becomes a legitimate tool for shaping it. In either case, the processing must strengthen the concept rather than overshadow it. This tension between a scientific and an artistic orientation already runs through the project's history — it was one of the central difficulties of the first semester — and it is one of the questions the prototyping phase is meant to answer.

The following blogposts document this phase: the mechanical build, the component tests, and the first closed feedback loops, up to the completed prototype.

Bibliography

Lucier, Alvin. 1969. “I Am Sitting in a Room.”.