

# THE “RAGION TROPICA” TACTICS: INHABITING THE VIBRATION, AUDIO CARTOGRAPHY, SOUND ROUTES, AND OTHER USELESS HACKING TOOLS

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## ABSTRACT

Feedback-augmented instruments unveil unmapped sonic territory. Nevertheless, cartographic tactics can trace sound routes that notation renders repeatable. This paper documents practices that emerged from augmenting an orchestral timpani with electromagnetic feedback: geometric spatial discretisation, exhaustive cataloguing of tridimensional samples, numerical analysis, and graph plots yield maps and performative notation. Each phase arose through sustained engagement with the instrument’s particular constraints—cataloguing revealed analytical needs, analysis suggested notational possibilities, notation exposed cataloguing gaps—a circular process termed *ragion tropica* (tropic reason), which operates through tactical circulation, guided by the material itself. The graphs that emerge from this circular process—where nodes represent catalogued sounds and edges encode timbral proximity in descriptor space—function as sound routes: performative trajectories through organised territory that the composer traces, producing frameworks and scores which preserve navigational flexibility, sustaining the performer’s agency within the very constraints that make compositional discourse possible.

## 1. INTRODUCTION

Self-designing musical instruments reshape practice by blending invention and performance, changing maker-tool-concept links. In the act of making, an ethical dimension [1] of epistemic manipulation persists: the hand that shapes its material produces knowledge exceeding the object it yields. Within a historically informed *practice*,<sup>1</sup> the continuous redefinition of instruments forms a permanent spine of thought. The reshaping of tools and the knowledge born from their making converge, each becoming the condition for the other’s renewal.

In 2022, I augmented an orchestral timpani through electromagnetic actuation [2, 3], allowing it to vibrate through gestural induction without physical contact and producing

<sup>1</sup> The term echoes but deliberately extends the notion of Historically Informed Performance (HIP): here, historical, scientific, and philosophical awareness informs the interpretation of repertoire and the practice of instrument-making and electroacoustic experimentation itself.

timbral variations unattainable with traditional techniques. However, this expanded capability revealed uncharted territory: the absence of a controllable system, the lack of methods for prescribing gestures, and the absence of an established basis for compositional organisation.

Between 2022 and 2025, I developed systematic methods: discretising the instrumental domain into spatial categories, cataloguing three-dimensional audio samples, extracting numerical data using descriptors, constructing navigable maps, and designing notation systems. These methods, which preceded and motivated the doctoral project *canto alla durata*,<sup>2</sup> are now being formalised within that research framework. What follows documents this trajectory as it took shape: through sudden laboratory discoveries and gradual refinement over time. I refer to this practice as *ragion tropica* (tropic reason) [5, 6]: a tactical circumambulation.

*How can the sonic capabilities of electroacoustically enhanced instruments be organised into clear, repeatable methods for musical composition?*

These organisational questions emerged within a broader inquiry into musical experience; the focus here is on the notational and cartographic dimensions of that research, resonating with Giorgio Netti’s [7] persistent question: *what is an instrument?*

My attempt to answer that question passes through practice: the laboratory becomes the site where the instrument is explored, an epistemic thing whose behaviour is not yet fully determined, and the question expands: *what is an electroacoustic instrument? An augmented one?* The work presented here is grounded in workshop experimental practice.

## 2. AN INSTRUMENT’S PLACES

The laboratory practice at the core of this work has been conducted since 2022 at LEAP (Laboratorio ElettroAcustico Permanente),<sup>3</sup> a permanent electroacoustic workshop based in Rome. The *Tempo* (Timpani Electro-Magnetic Pulse Oscillation) is the case study through which these practices are documented.

<sup>2</sup> Doctoral programme in Artistic Research in Music, Conservatory of L’Aquila (DOT24BX87A, DM 629 University/Afam: CUP D11I24001070006). The project title *canto alla durata* (song to duration) derives from Peter Handke’s *Gedicht an die Dauer* [4].

<sup>3</sup> [www.leaphz.net](http://www.leaphz.net)



**Figure 1.** The *Tempo* instrument at LEAP laboratory: Adams Revolution 29” hand-hammered copper timpani with tetrahedral microphone array, neodymium magnet pairs on the membrane, and geometric tracings of the *Due Lune* map. On the left, the SSL BiG SiX mixer and the power amplifier driving the induction system; on the right, a S.T.ONE tetrahedral loudspeaker.

## 2.1 The *Tempo* Instrument

The organisational challenge arose directly from the instrument’s technical capabilities: once electromagnetic fields enable contactless vibration at any membrane point and support infinite gestural combinations, how does one move from infinite technical possibility to organised musical territory? The threshold of a musical instrument (understood as a device yielding predictable results for given actions) requires a reference system. A tactical pattern gradually revealed itself: spatial discretisation (transforming the continuous membrane surface into discrete positions), exhaustive cataloguing (systematic documentation of sonic possibilities), numerical analysis (reducing acoustic complexity to navigable parameters), and graph-based notation (constructing performative frameworks). This cartographic approach operates through controlled reduction, making the instrument’s expressive potential accessible, repeatable, and communicable: essential prerequisites for compositional discourse.

The *Tempo* instrument achieves contactless excitation through two electromagnetic inductors, mounted on wearable gloves, operating on the same principle as conventional loudspeaker drivers: audio signals drive coils, generating magnetic fields that, when brought near ferromagnetic targets, induce vibration. Rather than activating a loudspeaker cone, these fields act upon neodymium magnets anchored to the timpani membrane in pairs: each magnet on the upper surface is coupled to a twin below, sandwiching the membrane between them and fixing the assembly at a precise position.

The magnets occupy four discrete positions on the membrane, determined through geometric construction, establishing the spatial reference system that grounds the discretisation phase generating six distinct instrumental con-

figurations, each characterised by unique acoustic coupling between membrane zones and electromagnetic activation patterns.

Each configuration binds together a gestural repertoire, an acoustic space, and its electroacoustic extension—three interdependent dimensions that the following sections examine in turn.

## 2.2 Gesture

Sound production occurs through controlled proximity between wearable inductors and membrane-mounted magnets. The gesture of bringing the hands together—moving the inductors towards the magnets—initiates or modulates vibration. Distance governs amplitude: closer proximity increases induced vibration intensity, while greater distance attenuates or extinguishes feedback.

Contactless excitation differs fundamentally from traditional beater techniques: the electromagnetic field activates vibration from silence without percussive attack, sustains indefinitely through gestural maintenance, and develops dynamic contours impossible with struck techniques—opening access to the membrane’s sustained vibrational modes. Pedal control introduces a second gestural dimension, allowing continuous pitch variation during sustained sounds.

The combination of inductor positioning (selecting membrane activation zones), distance modulation (controlling amplitude and feedback intensity), and pedal manipulation (varying membrane tension and thus pitch) generates a three-dimensional gestural space. Navigating this space requires systematic organisation—hence the necessity of discretisation, cataloguing, and notational frameworks that gradually emerged as the *region tropica* approach.

## 2.3 Acoustic Space

The *Tempo* is built upon an Adams Revolution 29” hand-hammered copper timpani, with fine-tuning system, as its acoustic foundation. I selected this configuration after a three-month evaluation examining diameter, materials, and mechanical design: the 29” hand-hammered copper with a low-pedal removable mechanism offered the optimal balance of dynamic response, timbral richness, and gestural control, while the fine-tuning mechanism enables micro-adjustments for precise intonation—crucial when working with feedback-generated pitches.

I arrived at this choice through a process of elimination: tests yielded encouraging results across different bowl materials, including fiberglass models; however, high-pedal mechanisms proved impractical for the slow glissandi that electromagnetic feedback demands. The low-pedal design allows continuous, controlled pitch variation without the abrupt mechanical resistance that high-pedal systems impose at the extremes of their range. Economic constraints further narrowed the choice: professional-grade instruments were excluded in favour of a configuration whose cost remains compatible with project replication.

The current project employs a single timpani. The electroacoustic chain, described in the following section, is

entirely analogue and modular: each channel strip operates independently, making the system scalable to a full orchestral set without architectural redesign.

## 2.4 Electroacoustic Space

Fig. 2 shows the complete signal path. Four microphones, positioned to form a regular tetrahedron around the membrane's centre, capture vibrations and provide a three-dimensional acoustic representation of the membrane's vibrational modes. The tetrahedral arrangement supports spatial analysis of sound distribution across the surface, revealing how electromagnetic excitation couples differently to different membrane regions. The four analogue-processed channels drive the electromagnetic inductors, closing the loop: membrane vibration  $\rightarrow$  microphone capture  $\rightarrow$  analogue signal processing  $\rightarrow$  electromagnetic excitation  $\rightarrow$  membrane vibration. The recursive nature of this configuration is the instrument's defining characteristic, producing self-sustaining oscillation and gestural control of feedback behaviour [8].

Each inductor consists of a parallel network of two symmetric branches—each placing a halogen lamp in series with two magnetic coils—driven by a power amplifier's speaker output (Fig. 3). The coils generate the electromagnetic field that activates the membrane's neodymium magnets. The circuit behaves as a dynamic low-pass filter: the inductors' impedance rises with frequency, while the halogen filament's resistance increases with temperature, simultaneously compressing amplitude and shifting the spectral balance toward higher frequencies. This temperature dependence makes the inductor a non-linear, signal-dependent system whose timbral contribution changes with the signal passing through it—an active participant in the feedback loop. The parallel combination yields a total DC impedance of approximately  $5.5\ \Omega$ , compatible with standard power amplifier speaker outputs.

The signal chain diagram (Fig. 2) and the inductor schematic (Fig. 3) constitute two levels of electroacoustic writing: the first notates the flow of audio signals through the system; the second notates the physical mechanism by which electrical current becomes mechanical vibration. Both are forms of prescriptive notation—they specify behaviour, enable replication, and remain open to interpretation through component selection and tuning. The electroacoustic chain writes vibration onto the membrane; the circuit diagram writes the design that makes this writing possible.

Once the electroacoustic system is established and its behaviour documented, the question shifts from how vibration is produced to how its sonic results can be organised—the cartographic work that the following section details.

## 3. THE CARTOGRAPHIC METHOD

The cartographic method traces a directed chain—catalogue, analysis, graph, annotated graph, framework, agenda—where each phase crystallises the output of the preceding one: the catalogue's combinatorial richness is focused by analysis, structured by graph computation, annotated with

compositional signs, temporally ordered by the framework, and fixed in the score.

### 3.1 Spatial Discretisation

The reference system that the instrument required emerged through geometric necessity. Using four magnetic positions derived from Hippocrates' lunes (Fig. 4), I generated six distinct instrumental configurations that provide the spatial framework for subsequent cataloguing work.

The geometric discretisation of the membrane surface derives from the classical problem of Hippocrates' lunes, two intersecting circular arcs that define calculable curvilinear regions. Applied to the timpani membrane, this construction defines four magnetic constraints, denoted  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ , relative to the centre point  $N$  (North), as shown in Fig. 4.

Each neodymium sandwich pair grips the membrane through mutual magnetic attraction (approximately  $6Kg$  pull force per pair), holding its position without mechanical fastening. Sliding the pair along the surface with sufficient force allows repositioning at any of the four nodes. The six possible pairings define six distinct instrumental configurations:

- *Position I:*  $\alpha\beta$  (tight spacing between magnets)
- *Position II:*  $\beta\gamma$  (tight spacing)
- *Position III:*  $\gamma\delta$  (tight spacing)
- *Position IV:*  $\alpha\gamma$  (intermediate spacing)
- *Position V:*  $\beta\delta$  (intermediate spacing)
- *Position VI:*  $\alpha\delta$  (wide spacing)

The nomenclature follows ordinal distance logic—positions with closer magnetic spacing (I–III) precede those with intermediate (IV–V) and maximum (VI) spacing—transforming the continuous membrane surface into a navigable, discrete territory. Each position produces distinct acoustic coupling between membrane zones and electromagnetic activation patterns (Fig. 7), yielding characteristic timbral behaviours (Fig. 10).

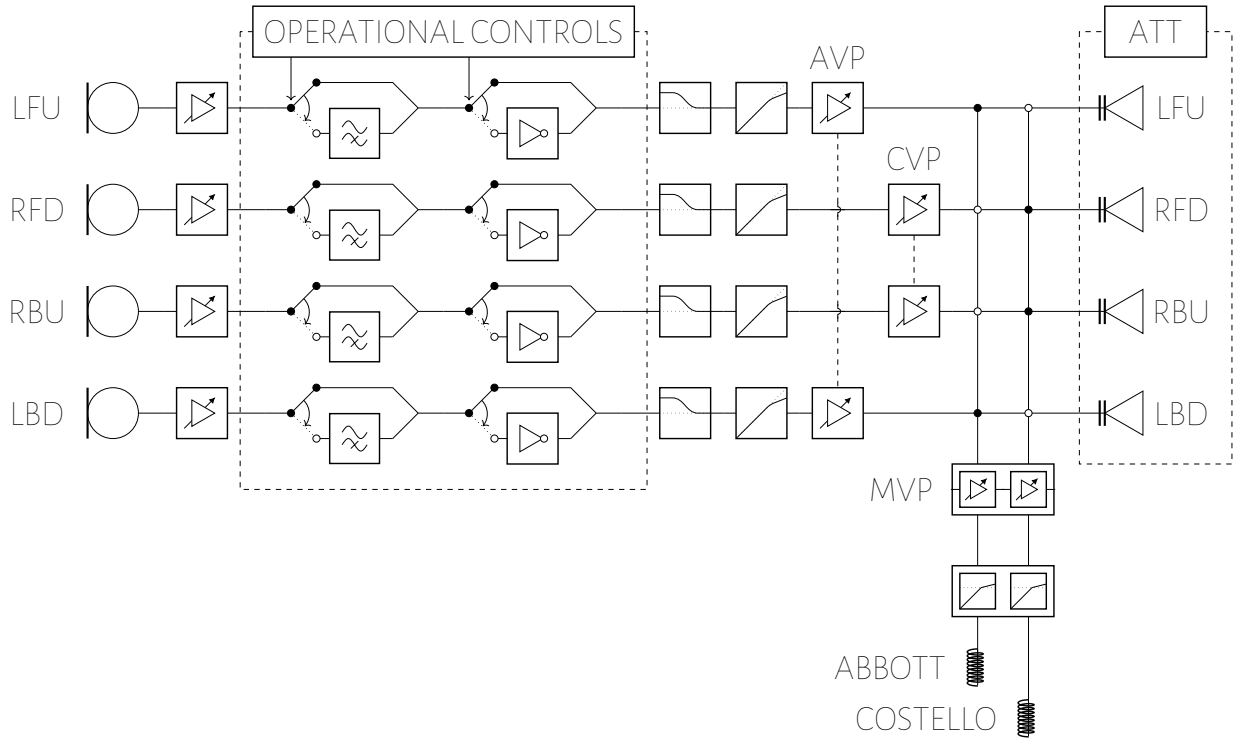
Two intersecting arcs traced on the membrane surface establish the spatial reference system; magnetic constraints materialise as positioned inductors at calculated coordinates. The physical inscription embodies the transition from geometric abstraction to operational territory—from theory to practice (Figs. 5, 6).

### 3.2 Catalogue

With six spatial positions defined, the cataloguing process methodically addressed the combinatorial space. For each position, I documented 72 quadraphonic samples along two control dimensions.

Firstly, the pedal tension (12 positions, 0–11): from minimal to maximum membrane tension, producing continuous pitch variation across approximately one octave per position. Pedal positions were indexed numerically for precise replication across sessions.

Secondly, the inductor configuration (6 possibilities): single-inductor activations ( $\alpha(A)$ ,  $\gamma(A)$ ,  $\alpha(C)$ ,  $\gamma(C)$ ) plus two-inductor combinations ( $\alpha(A)\gamma(C)$ ,  $\gamma(A)\alpha(C)$ ) (here exemplified for Position IV). The two-inductor configurations produce “electromagnetic chords”—simultaneous



**Figure 2.** Electroacoustic analogue signal chain of the *Tempo* instrument. Four omnidirectional microphones, in a tetrahedral spaced configuration, capture membrane vibrations. An SSL BiG SiX analogue mixer processes each channel through three-band equalisation (LF shelf at 60 Hz boosted to compensate inductor roll-off) and channel compression (limiting feedback peaks); the G-Series bus compressor provides a second limiting stage on the summed signal before it drives electromagnetic inductors (*Abbott* and *Costello*) positioned on the membrane surface, creating recursive feedback. AVP (*Abbott* Volume Pedal) and CVP (*Costello* Volume Pedal) control individual inductor intensity via expression pedals; MVP (Master Volume Pedal) governs the overall feedback level. ATT (Amplificazione Tetraedrica Trasparente) provides tetrahedral sound reinforcement through spherical loudspeakers (S.T.ONE)—a predisposition, not a requirement: the instrument is entirely analogue and self-contained. The BiG SiX USB interface enables 96 kHz digital capture for cataloguing purposes.

activation of two membrane zones generating interference patterns and coupled resonances.

The resulting 72 samples per position ( $12 \times 6 = 72$ ), multiplied across six positions, yield 432 documented sounds—the complete catalogue of the *Tempo* instrument’s systematically organised sonic territory (Fig. 9). The waveform displays (Fig. 8) reveal spatial signatures across the four channels: sample  $7\gamma(C)$  shows balanced energy distribution, while  $11\alpha(C)$  concentrates energy in channels 1 and 3, distinguishing distributed from membrane-localised responses.

The catalogue functions as constitutive documentation [9]: the act of cataloguing shapes understanding of the material, revealing patterns and necessitating analytical frameworks.

My cataloguing was non-linear and reiterative. I re-catalogued each position as tuning procedures evolved from exploratory tunings towards the systematic *D3*-referenced protocol documented in Sec. 4.1. I catalogued the first three positions (Studies I-III) with less refined tuning; Position IV was the first generated with a consolidated tuning method. The temporal dimension—the catalogue as a document of evolving technical mastery—remains legible in the materials: early catalogues exhibit greater pitch variability, while later catalogues show tighter intonation control.

The catalogue numbers (Fig. 9) encode this systematic-

sation: each sample identifier specifies position, inductor configuration, and pedal state, for precise recall and replication.

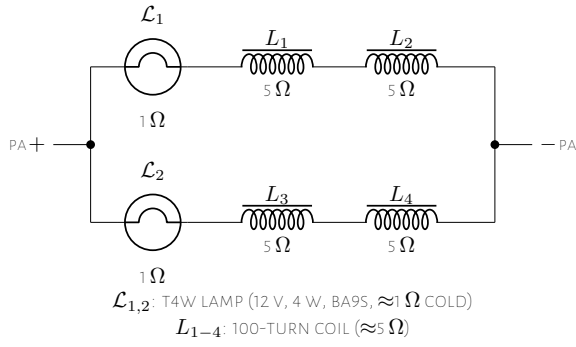
### 3.3 Analysis

The 72 quadraphonic samples per position required reduction to a navigable form. Raw audio provides too much information: waveforms, spectral content, spatial distribution, temporal evolution—all simultaneously present, all relevant, all overwhelming when multiplied across hundreds of samples.

I implemented numerical analysis in Wolfram Mathematica to extract quantitative descriptors from each sample.

```
SetOptions[SelectedNotebook[],
  PrintPrecision -> 5];
files = FileNames["*.wav",
  NotebookDirectory[]];
collection = Import[#] & /@ files;
qualities = AudioMeasurements[
  collection,
  {"SpectralSpread",
    "LoudnessEBU",
    "SpectralRollOff"},
  "List"];
```





**Figure 3.** Circuit diagram of the electromagnetic inductor network (mk01) for *Abbott and Costello*—named after the heptapod linguists in Denis Villeneuve’s *Arrival* (2016), whose cavernous vocalisations the first sounds produced by the instrument recalled. Two symmetric branches share the power amplifier output: each branch places a halogen lamp ( $\mathcal{L}_{1,2}$ ) in series with two coils ( $L_{1-4}$ ). The schematic operates as a form of circuit transcription, prescribing electron flow as a score prescribes sonic behaviour.

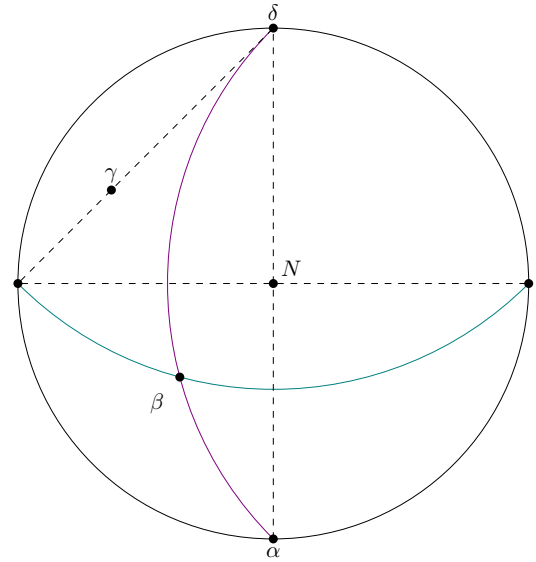
Three descriptors turned out to be particularly useful for distinguishing timbral territories:

**Spectral Spread** measures the bandwidth of spectral content—how widely energy is distributed across the frequency spectrum. A narrow spread indicates focused spectral energy (near-sinusoidal behaviour); a wide spread suggests rich harmonic or inharmonic content. Spectral Spread distinguished membrane-localised sounds (narrower spread) from bowl-resonant behaviours (wider spread due to coupled resonances).

**Loudness EBU** quantifies intensity using the European Broadcasting Union standard (measured in LUFS—Loudness Units relative to Full Scale). Standardised measurement enables comparison across samples recorded in different sessions, accounting for variations in electromagnetic coupling efficiency and membrane response. Loudness values revealed how pedal tension affects vibration amplitude.

**Spectral Roll-Off** identifies the frequency below which a specified percentage (typically 85%) of spectral energy concentrates. Roll-Off captures the distinction between bass-heavy membrane vibrations and brighter bowl resonances. Roll-off values also showed that two-inductor configurations produce different spectral balances from single-inductor configurations.

The analysis produced a dataset organising the 72 samples for each position in three-dimensional descriptor space (Spectral Spread, Loudness EBU, Spectral Roll-Off). Numerical reduction transformed acoustic complexity into navigable coordinates—each sample now occupies a specific location in this abstract space, with proximity indicating timbral similarity.



**Figure 4.** Theoretical map *Due Lune, Ippocrate su pelle* (Two Moons, Hippocrates on skin). Spatial discretisation of the membrane surface determines four magnetic constraints ( $\alpha, \beta, \gamma, \delta$ ) in relation to the centre point  $N$  (North). The map generates six positions, each with its own tuning.

These three descriptors emerged through pragmatic experimentation: other candidates (spectral centroid, harmonic-to-noise ratio, spectral flux) provided less effective differentiation for this instrument’s behaviours.

### 3.4 Graph

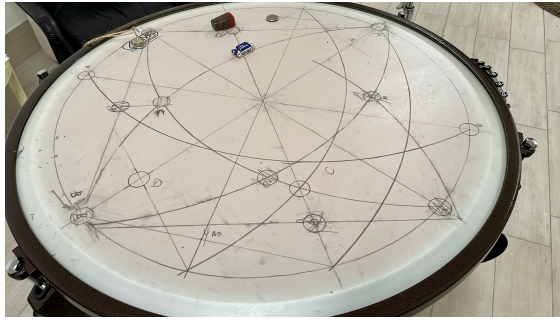
```
FindSpanningTree[
  qualities,
  PlotTheme -> "Monochrome",
  VertexLabels -> Placed[
    {"Index"}, {Center}],
  VertexSize -> .5]
```

The three-dimensional descriptor space (Spectral Spread, Loudness EBU, Spectral Roll-Off) provided the basis for graph construction. Using Mathematica’s spring-embedded layout algorithms, I generated graphs where:

- *Nodes* represent individual catalogued samples
- *Edges* connect samples that are proximate in descriptor space
- *Spatial layout* reflects timbral relationships: proximate nodes sound similar, distant nodes sound distinct

The spring-embedded algorithm treats nodes as physical objects connected by springs—strong connections (similar descriptors) pull nodes together, while dissimilar nodes repel each other. The algorithm iterates until a stable configuration is reached, producing two-dimensional visualisations of three-dimensional proximity relationships.

Six graphs emerged, one per position (see example for Position IV in Fig. 11). Each graph reveals a distinct topological structure reflecting that position’s timbral territory. Some graphs exhibit apparent clustering—groups of tightly



**Figure 5.** Exploratory geometric constructions pencilled on the timpani membrane during the search for the definitive *Due Lune* configuration. Successive attempts to project the theoretical cartography onto the physical surface accumulate as overlapping arcs, intersections, and candidate constraint points—a palimpsest of the discretisation process.

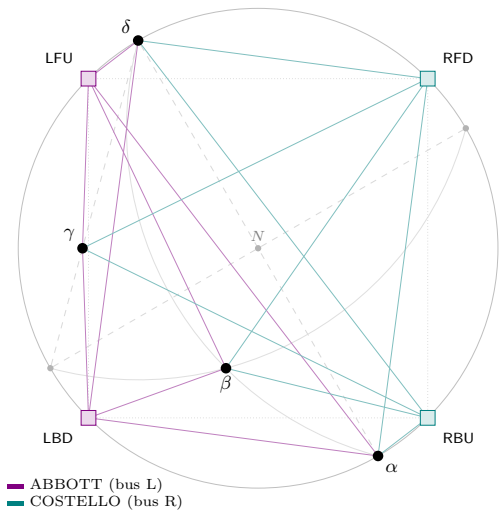


**Figure 6.** Top view of the freshly traced *Due Lune* (Two Moons) cartography on the membrane, with neodymium magnets still off-position. The four constraint points arise from distinct geometric intersections:  $\alpha$  from lune and circumference,  $\beta$  between the two lunes,  $\gamma$  on an external triangular intersection axis,  $\delta$  from circumference and lune—replicating the theoretical map of Fig. 4.

connected nodes representing timbral families—while others show more distributed structures suggesting continuous gradation.

These topological differences reflect fundamental acoustic distinctions between positions. Position I, with tight magnetic spacing  $\alpha\beta$ , generates relatively homogeneous responses—the graph shows few distinct clusters. Position VI, with maximum spacing  $\alpha\delta$ , activates a more diverse set of membrane zones—the graph exhibits pronounced clustering, with each cluster corresponding to a distinct coupling mode between the membrane and bowl.

The graphs function as navigational tools: pathways through the graph suggest performative trajectories—sequences of sounds connected by timbral proximity. Edges between nodes generate smooth timbral evolution; jumping between disconnected clusters produces abrupt timbral shifts. The graph structure thus encodes both similarity (connected nodes) and contrast (disconnected regions), pro-



**Figure 7.** Microphone placement on the *Due Lune* map. The lune pattern is rotated to match the actual membrane orientation—a rotation found empirically through successive attempts to optimise the microphone-to-map relationship. Rays connecting each microphone to the induction nodes reveal the varying distances that shape distinct feedback modes across the six instrumental positions.

viding a compositional vocabulary that preserves performer agency.

Within the directed chain, the graph marks a pivot: the open analytical potential accumulated through cataloguing and descriptor extraction begins here to solidify into compositional structure.

### 3.5 Annotated Graph

The graph is an analytical object: its topology is fixed by computation and descriptor proximity. Annotation transforms it into a compositional tool—a spatial instrument for studying trajectories, exploring deviations from ordinary paths, and composing itineraries through timbral territory. The temporal dimension remains absent: it is the framework that converts spatial routes into scored time.

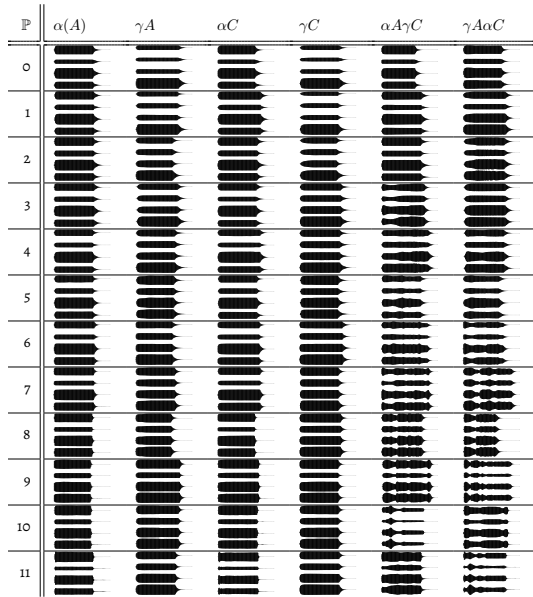
Fig. 11 shows the annotated graph for Position IV. Each node receives multiple annotations:

**Sample index** The catalogue number for precise recall (e.g., sample 23 = pedal position 3, inductor configuration  $\alpha(A)\gamma(C)$ );

**Pitch notation** The fundamental frequency in cent-precise notation at an A=442Hz reference;

**Timbral character** Brief descriptive labels emerging from listening—“membrane”, “bowl”, “coupled”, “unstable”—functioning as performative reminders.

The annotation process revealed that graphs function as maps requiring keys—the topological structure provides spatial relationships, but performers need concrete referents



**Figure 8.** Catalogue of waveforms for the 72 quadraphonic samples. Each cell displays four waveforms (tetrahedral microphone array). Rows index pedal tension positions ( $P$  : 0 – 11); columns indicate inductor configurations:  $\alpha(A)$ ,  $\gamma(A)$ ,  $\alpha(C)$ ,  $\gamma(C)$ , and two-inductor combinations  $\alpha(A)\gamma(C)$ ,  $\gamma(A)\alpha(C)$ .

to navigate the territory. The sample indices connect abstract nodes to specific sounds in the catalogue; the pitch notations provide melodic reference; the character labels offer timbral orientation.

Pathways through the annotated graph suggest compositional strategies. Following connected nodes generates smooth timbral progressions—each transition moves to a neighbouring sound in descriptor space, producing gradual evolution. I trace routes through the graph: node 12 → 15 → 23 → 31 defines a specific timbral trajectory, a composed pathway through the instrument’s organised sonic territory.

The graphs preserve agency: they organise possibilities while leaving outcomes open. Multiple pathways connect any two nodes; disconnected regions invite sudden jumps; cyclic paths enable returns and variations. The notation captures relationships—this sounds like its neighbours. The performer navigates the map; the map does not choreograph the performance. The structure resonates with Borges’ labyrinths [10]: maps that preserve the possibility of getting lost while providing orientation.

### 3.6 Framework

The annotated graphs organise sonic territory spatially but require temporal instantiation for performance. The need gave rise to the *telaio* (framework)—a notational structure that transcribes spatial graphs into temporal sequences while preserving navigational flexibility.

Fig. 12 shows the framework for Position IV’s Study. The notation operates through multiple simultaneous layers:

| INDEX | CODICE | ABBOTT | COSTELLO | PEDALE | R442  | Hz    |
|-------|--------|--------|----------|--------|-------|-------|
| 1     | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 2     | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 3     | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 4     | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 5     | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 6     | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 7     | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 8     | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 9     | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 10    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 11    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 12    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 13    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 14    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 15    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 16    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 17    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 18    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 19    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 20    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 21    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 22    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 23    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 24    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 25    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 26    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 27    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 28    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 29    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 30    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 31    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 32    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 33    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 34    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 35    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 36    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 37    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 38    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 39    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 40    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 41    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 42    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 43    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 44    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 45    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 46    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 47    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 48    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 49    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 50    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 51    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 52    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 53    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 54    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 55    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 56    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 57    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 58    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 59    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 60    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 61    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 62    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 63    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 64    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 65    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 66    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |
| 67    | AV-000 | α(A)   | 000      | 000    | 120.0 | 120.0 |
| 68    | CV-000 | γ(A)   | 000      | 000    | 120.0 | 120.0 |
| 69    | AV-000 | α(C)   | 000      | 000    | 120.0 | 120.0 |
| 70    | CV-000 | γ(C)   | 000      | 000    | 120.0 | 120.0 |
| 71    | AC-000 | α(A)   | γ(C)     | 000    | 120.0 | 120.0 |
| 72    | CA-000 | γ(A)   | α(C)     | 000    | 120.0 | 120.0 |

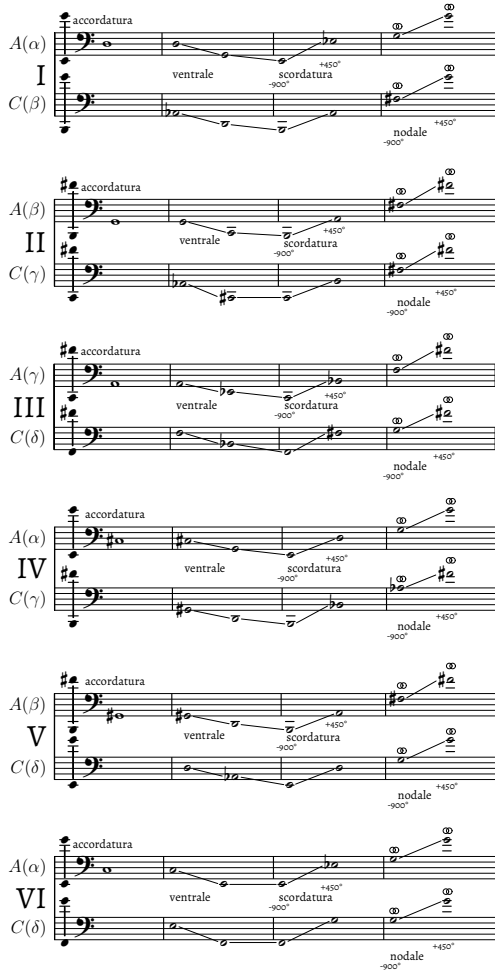
**Figure 9.** Systematic catalogue of the 72 samples for position IV. Columns: INDEX (progressive numbering), CODICE (audio file identifier), ABBOTT/COSTELLO (inductor positions:  $\alpha$  or  $\gamma$  in configurations A or C), PEDALE (tension pedal positions 000–110), R442 (pitch in cent-precise notation at A=442Hz), Hz (fundamental frequency). The catalogue organises the combinatorial space: 12 pedal positions  $\times$  6 inductor configurations = 72 samples per position.

**Upper metadata strip** Records the sample name (linking the framework to the catalogue), the node identifier (linking it to the graph), and a section label (intro, A, B, etc.) for structural organisation. Each vertical line represents a node (catalogued sound); horizontal reading generates a timbral contour.

**Central strip** Traces the pedal tension profile across the sequence, notating membrane tension contour as a continuous line.

**Lower staves** Indicate inductor positions and activation states. Four lines represent the four magnetic positions ( $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ ); filled circles show active inductors, empty circles inactive.

The framework is not a performance score but a compositional tool: I read it at the instrument, testing the oriented sequence of actions against the instrument’s actual behaviour. Choices made at the annotated graph stage are transcribed into the framework and explored in sequence, allowing me to understand how the material unfolds in time—how gesture relates to duration through the instrument’s feedback response. The framework is thus a scaffold for writing the



**Figure 10.** Timbral ranges (*ambiti*) of the six positions. Each position displays: *accordatura* (fundamental reference pitch), *ventrale* trajectory toward membrane centre (belly region,  $-900^\circ/+450^\circ$  cent deviations), *nodale* trajectory toward nodal regions, for both inductors *Abbott* and *Costello*. The systematic documentation reveals how membrane tension couples with electromagnetic positioning to generate distinct sonic territories.

agenda: it is where I learn from the instrument before the final score crystallises.

### 3.7 Agenda

The frameworks (*telai*) for each position provide navigational structures yet require integration into coherent performative works. I composed the *Sei Studi di Agamotto sul Tempo* (Six Studies of Agamotto on Tempo) as the final stage (Fig. 13)—six studies that function simultaneously as a pedagogical progression, a technical exploration, and musical compositions.

The term *agenda* (from Latin *agere*, to do/act) designates these performative scores as action-oriented. This orientation resonates with recent calls to develop notation conventions that acknowledge the role of technology as a constitutive element of augmented instrument works [11].

Each Study organises its framework materials according

to distinct compositional strategies:

Studies I–III (*Studi Tecnici*, Technical Studies) systematically explore the progressive technical complexity: from fixed electromagnetic output (Study I) through unified dynamic control (Study II) to independent inductor control (Study III).

Studies IV–VI (*Studi Espressivi*, Expressive Studies) transition towards musical expression, applying technical mastery to compositional invention. These studies employ graph-based frameworks with greater freedom: longer pathways through descriptor space, more complex timbral trajectories, and attention to large-scale formal arcs.

The Studies also reveal temporal layering: Studies I–III were composed in 2022, Study IV in spring 2024; Studies V–VI are currently in progress. The chronological sequence documents a learning trajectory—the Studies preserve the progressive mastery of the instrument’s capabilities through their increasing compositional ambition. Alongside Studies V–VI, I am developing a solo work that moves beyond the position-by-position structure of the Studies: a piece that draws on the full range of possibilities revealed across all six positions, integrating the instrument’s capabilities into a unified compositional argument.

## 4. TRANSFORMATIVE PRACTICES

The cartographic chain presupposes practices of a different order: the operational work of tuning and stabilising *Tempo* for systematic exploration, and the epistemic positioning of augmentation within a broader tradition of transformative practices.

### 4.1 Operational Practices

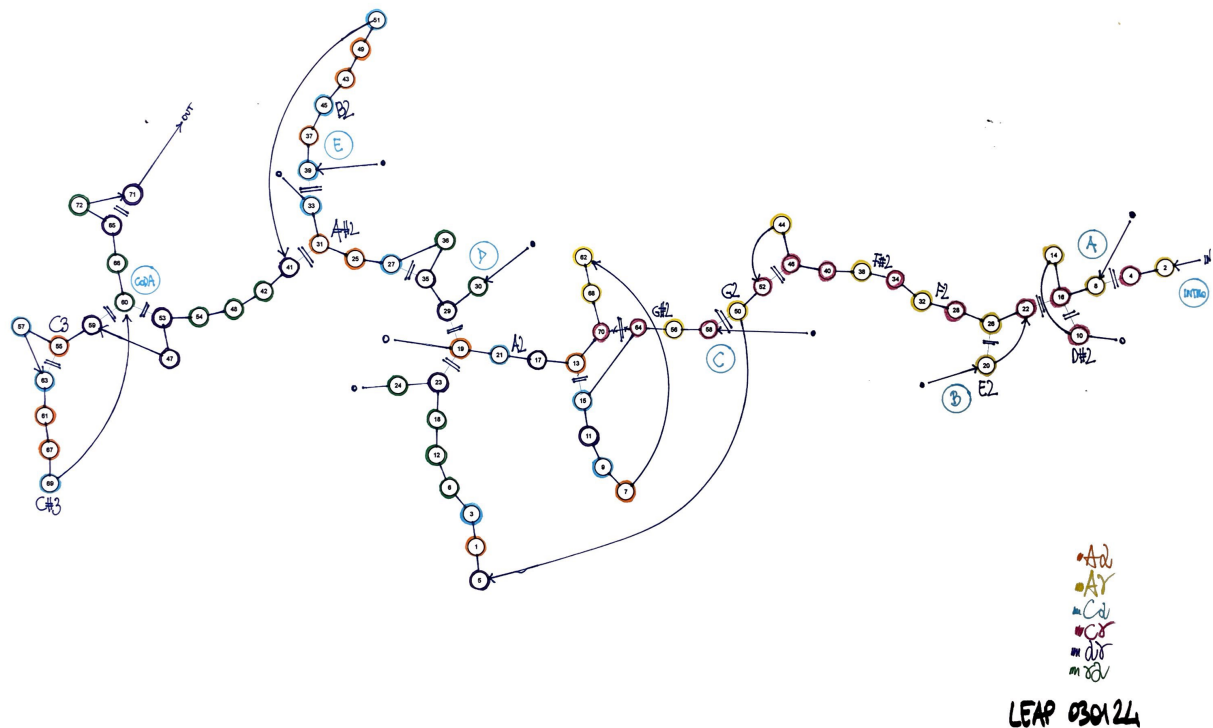
I developed the tuning practice iteratively, moving from exploratory “travelling” tunings towards systematic, replicable procedures.<sup>4</sup> The current standardised tuning protocol establishes Position I as the reference configuration: inductor *Abbott* activating magnet  $\alpha$ , pedal tension at maximum (position 11), fine-tuning set to zero degrees, yielding  $D_3$  at  $442Hz$  concert pitch. Investigating membrane-bowl coupling revealed explosive resonance around  $D_3$  after acoustic annihilation around  $C\sharp_3$ : this discovered phenomenon provides the reference pitch for the entire tuning system. From this  $D_3$  foundation in Position I, the fine-tuning mechanism extends the tuning across the six positions, covering a comprehensive pitch range. (Fig. 10)

Tuning stability requires careful attention to mechanical detail. The membrane must undergo repeated cycles of tension and release during setup to stabilise its molecular structure. Individual tension rods require individual verification: counting exposed thread turns for each bolt ensures homogeneous tension distribution around the membrane’s circumference. Any compensation adjustments require subsequent pitch verification.

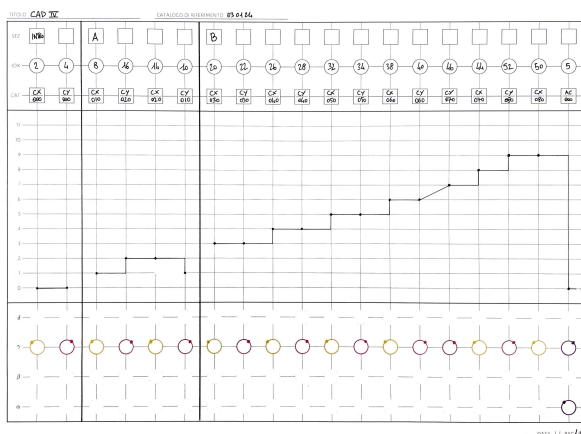
Signal robustness is verified through polarity testing: rapid polarity inversions should produce an immediate feedback

<sup>4</sup> Video documentation of the tuning procedures and other video about *Tempo* are available at: <https://www.youtube.com/playlist?list=PLLfETWgVXqYaoOSBXed7lGm2BG77-QHhL>

CAD IV dr



**Figure 11.** Annotated graph of position IV. Each node represents a catalogued sample; connections indicate three-dimensional proximity in descriptor space (Spectral Spread, Loudness EBU, Spectral Roll-Off). The marked pathway traces a composed route through the timbral territory: the entry point is arbitrary—a compositional choice that determines where the study begins. Other graphs are read with different logics (e.g. left-to-right traversal, alternative deviation strategies). The framework (Fig. 12) transcribes the chosen route into temporal notation.



**Figure 12.** Gestural framework (*telaio*) for Position IV, transcribing the annotated graph (Fig. 11) into temporal notation. Upper metadata strip: sample name, graph node identifier, and section label (intro, A, B...). Central strip: pedal tension profile as a continuous contour. Lower staves: four lines for magnetic positions ( $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ ); filled circles indicate active inductors, empty circles inactive. Each vertical alignment represents one catalogued sound; horizontal reading generates the timbral trajectory of the study.

response at the lowest available pitch for the current configuration. Engaging the high-pass filter eliminates out-of-band signals that could destabilise the feedback system. These verification procedures, developed through concert experience (particularly the LAZZARO project concert series 2023-2024),<sup>5</sup> evolved from hour-long pre-concert preparations into rapid, reliable setup protocols.

## 4.2 Epistemic Practices

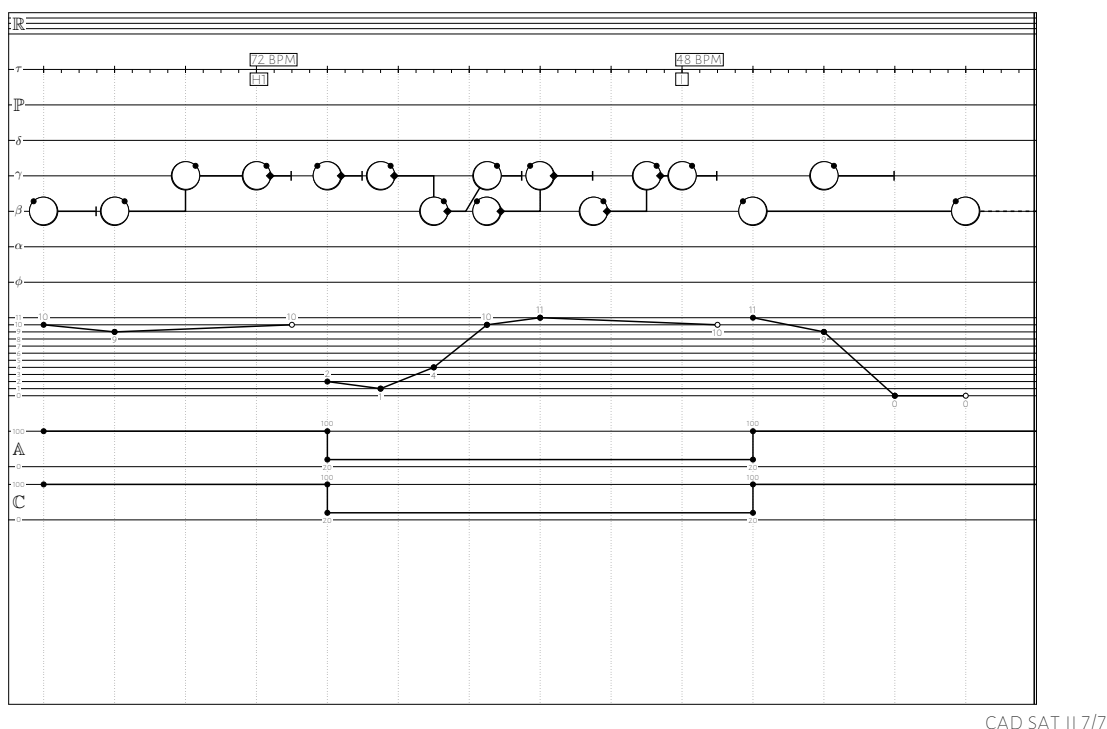
The practice of *preparation*, temporary physical modification of acoustic instruments, constitutes an established tradition from Cage to Netti, evolving from idiomatic exploration to ontological inquiry: each preparation defines a sonic world; the score navigates this world through controlled variations.

The electroacoustic *amplification* operates as ontological renewal, illuminating thresholds once unimaginable or private.

The *hacking* practice denotes creative tampering through unorthodox access to instrumental mechanisms, privileging intuition-driven exploration over systematic methodology. In this progression, I define *augmentation* as the

<sup>5</sup> [www.leaphz.net/lazzaro](http://www.leaphz.net/lazzaro)





**Figure 13.** Final page of the “score-agenda” (*partitura-agenda*), *Secondo Studio di Agamotto sul Tempo* (Second Study of Agamotto on Tempo). The upper staff, marked  $\mathbb{R}$ , is reserved for pitch transcription in traditional notation—a predisposition for communicating in conventional musical language, unused in this study but available for future works requiring it. Below, the framework (*telaio*) layers encode the gestural and electromagnetic structure of the performance.

extension of a traditional instrument’s expressive possibilities through electroacoustic complement, while preserving its physical principles and historical memory [12, 13]. The acoustic instrument retains its primary function and technical-expressive heritage; the electroacoustic system adds modes of excitation and articulation that are impossible with traditional techniques alone.

Augmentation synthesises aspects of previous practices—the systematic approach of preparation, the sonic revelation of amplification, the exploratory spirit of hacking—while introducing a crucial element: *recursive feedback* between the electroacoustic system and the acoustic resonator [3]. In my practice, recursive feedback is the operative principle that runs through hacking, augmentation, composition, and performance: it is at once the technical lever that enables contactless excitation, the force that demands new notational strategies, and the medium through which instruments and environment interact in concert [14, 15].

## 5. CONCLUSIONS

Inhabiting vibration demands cartography; cartography yields routes; routes require tools whose value remains bound to the territory that generated them.

The *racion tropica* tactics documented here trace a di-

rected chain through which the *Tempo*’s sonic territory became organised. Geometric discretisation of the membrane surface generated six instrumental positions; exhaustive cataloguing documented 432 quadrasonic samples across pedal and inductor configurations; numerical analysis reduced acoustic complexity to three navigable descriptors; graph computation revealed timbral proximity structures; notation transcribed spatial routes into temporal scores. The method did not precede practice: it revealed itself through sustained laboratory engagement with the instrument’s particular constraints, each phase’s output becoming the next phase’s material—cataloguing revealed analytical needs, analysis suggested notational possibilities, notation exposed cataloguing gaps. This circular movement confirmed that tactical circulation [16] through material generates organisational methods.

The tools that emerged—Hippocrates’ lunes traced on skin, tetrahedral capture, spring-embedded graphs, framework notation—are deliberately termed *useless* in Mario Bertoncini’s [17] sense of *bottega d’arte*: instruments of craft-based practice that operate through circulation and borrowing. This rationality, which María Zambrano’s *razón poética* [5, 6] names as *racion tropica* (from Greek *trópos*: turn, deviation, figure), proceeds tactically through the tension between invention and writing as instruments for un-

derstanding musical experience [18, 19, 20]. The *Sei Studi di Agamotto sul Tempo* preserve this trajectory as action-oriented scores—*agendae*—whose navigational flexibility sustains the performer’s agency within compositional constraints. The work positions itself within the Roman electroacoustic tradition, responding to Franco Evangelisti’s call for *un nuovo mondo sonoro* [21] through contemporary technical means, informed by the self-design principles of Enzo Mari’s *autoprogettazione* [1]: autonomy in judgement, integration of theory and praxis through the hand that shapes its material.

The *ragion tropica* pattern emerged through the *Tempo* instrument but exists within a broader research context. The doctoral project *canto alla durata* encompasses four hacked/augmented instruments—timpani, contrabass clarinet, cello, and voice—each representing a distinct instrument family. The organisational work documented here has been fully undertaken only for the timpani; the remaining instruments exist and function, their systematic exploration at varying stages of development. Maps do not make the territory navigable for the first time—experienced improvisers navigate uncharted ground—but they enable communicability and repeatability, prerequisites for compositional discourse beyond individual exploration. The ensemble dimension represents a further organisational challenge: coordinating multiple augmented instruments across distinct sonic worlds while sustaining tactical flexibility.

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