Deterministic Contextual Tuning via Regulated Mismatch Evaluation

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March 2026

Preprint — Semantis Research Series. This manuscript is shared for open review and has not yet undergone peer review.

1 Deterministic Contextual Tuning via Regulated Mismatch Evaluation

1.1 Introduction

Musical tuning systems must negotiate competing constraints between local harmonic relationships and global consistency. Traditional approaches either impose a fixed temperament or rely on adaptive mechanisms that adjust pitch over time. This work explores a third option: deterministic contextual tuning, in which pitch realizations are selected through a fixed evaluative rule applied to a discrete harmonic context.

The goal is not to minimize mismatch globally, nor to adapt continuously, but to select a realizable pitch configuration that best satisfies a bounded set of interval constraints. The method is fully deterministic, reproducible, and independent of performance history.

1.2 Scope and Non-Goals

This work deliberately restricts its scope to deterministic, static evaluation of harmonic contexts. It introduces no psychoacoustic claims, no adaptive or history-dependent behavior, no performance or listening evaluation, and no interpretive semantics. Diagnostic representations, when used, are strictly observational and do not participate in system behavior. These exclusions are design constraints, not omissions, and allow the structural properties of contextual selection to be examined in isolation.

1.3 Discrete Pitch-Class Framework

Let $P = \{p_1, \ldots, p_N\}$ denote a finite set of pitch classes. For any ordered pair (p_i, p_j), define an interval representation I_{ij} drawn from a bounded reference set $\mathcal{R}$.

The reference set $\mathcal{R}$ encodes admissible interval ratios and their associated mismatch costs. No assumptions are made regarding perception, cognition, or adaptation.

In practice, $\mathcal{R}$ may be instantiated as a finite subset of rational interval ratios (e.g., low-order just intervals) together with fixed tolerance bounds or cost weights. The formalism does not depend on any particular choice of reference lattice; $\mathcal{R}$ is treated as a bounded, static constraint set supplied a priori.

1.4 Interval Mismatch Evaluation

For a given harmonic context $H \subset P$, define a candidate realization x as an assignment of concrete pitch values to each element of H.

Define the total mismatch functional

$$W(x \mid H) = \sum_{(i,j)\in H\times H} w(I_{ij}(x), \mathcal{R})\,, \tag{1}$$

where $w(\cdot)$ measures deviation from the nearest admissible reference interval.

This functional (Eq.˜(1)) is evaluated once per candidate realization and does not depend on previous selections.

1.5 Deterministic Selection Rule

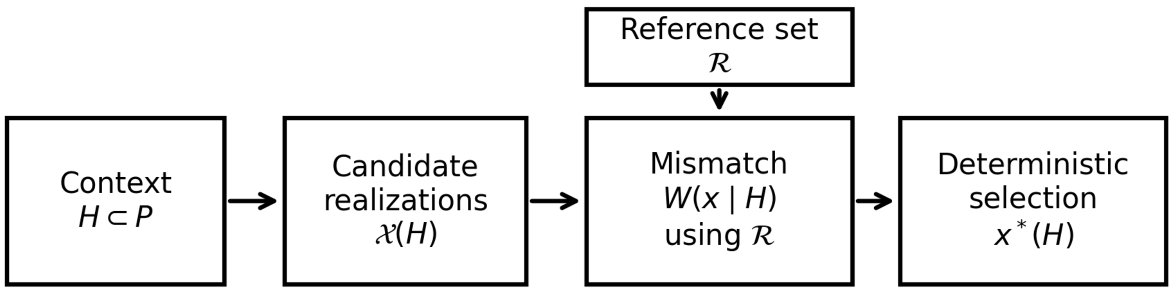

Figure 1: Deterministic contextual tuning: selection pipeline (schematic).

The contextual tuning rule is defined as

$$x^*(H) = \arg\min_{x\in\mathcal{X}(H)} W(x \mid H), \tag{2}$$

subject to fixed tie-breaking rules that guarantee uniqueness.

For finite harmonic contexts, the candidate realization set $\mathcal{X}(H)$ is assumed to be finite or discretized, consisting of a bounded neighborhood of realizable pitch assignments compatible with the reference lattice. This ensures that the selection rule is well-defined and that evaluation terminates without iteration or search over unbounded continua.

No iteration, update, or temporal dependence is introduced. Given the same context H, the selected realization is always identical.

1.6 Role of Residual Mismatch

Residual mismatch ("wolf" structure) is not treated as error to be eliminated, but as a structured constraint arising from the discreteness of the reference lattice. Certain harmonic contexts necessarily incur non-zero mismatch; the selection rule ensures this residual is localized and bounded.

1.7 Examples

This section provides a single worked formal instantiation of the deterministic selection rule. The example is intended solely to demonstrate that the rule is concrete, finite, and non-trivial; it makes no perceptual or performance claims.

Let the harmonic context be

$$H = \{p_1, p_2, p_3\}, \tag{3}$$

corresponding to a triadic pitch-class set.

Let the reference set $\mathcal{R}$ consist of the rational intervals

$$\left\{1,\ \tfrac{5}{4},\ \tfrac{3}{2}\right\}, \tag{4}$$

with fixed mismatch costs defined as absolute deviation from the nearest reference ratio (Eq.˜(4)).

Consider three candidate realizations $x_1, x_2, x_3 \in \mathcal{X}(H)$, each assigning concrete pitch values to the elements of H. For each realization, the total mismatch functional $W(x \mid H)$ is evaluated once using the same reference set.

Under this evaluation, one realization uniquely minimizes the total mismatch and is therefore selected by the deterministic rule. Given the same harmonic context and reference set, this selection is invariant and reproducible.

1.8 Scope and Limitations

This work addresses static harmonic contexts only. Temporal processes, adaptive control, feedback mechanisms, and performance-dependent behavior are explicitly out of scope.

Diagnostic renderings, when referenced, exist solely to support inspection and communication of outcomes and introduce no additional structure, state, or causal pathways.

1.9 Conclusion

Deterministic contextual tuning provides a transparent alternative to both fixed temperament and adaptive tuning approaches. By formalizing interval mismatch evaluation within a bounded lattice, it enables reproducible pitch realization without reliance on temporal dynamics or learning.

Appendix A

A Diagnostic Notation, Visual Legend, and Alternate Renderings

A.1 Scope

This appendix defines a **diagnostic-only notation** for representing the observable behavior of an adaptive intonation process, along with **alternate renderings** that support accessibility.

This appendix:

- introduces no new structure,
- introduces no new feedback or control paths,
- assigns no semantics or experiential meaning,
- and does not participate in decision-making.

All elements here are **Path C projections** only.

A.2 Polar Diagnostic Lattice (Visual Rendering)

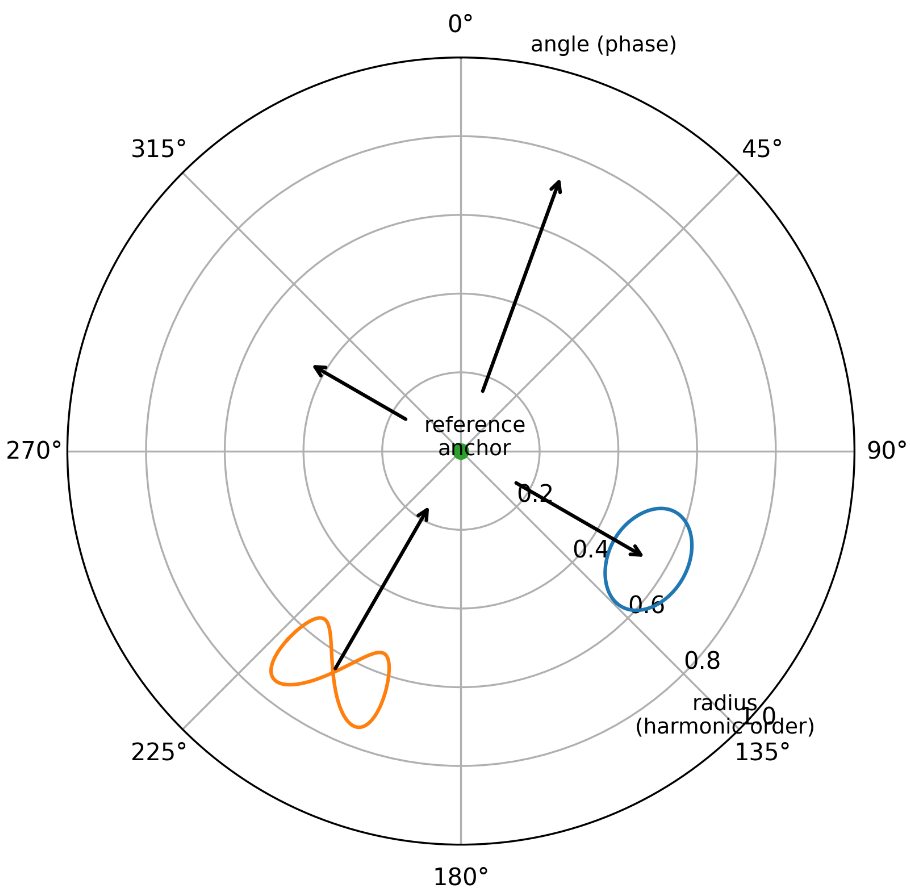

Figure 2: Polar diagnostic lattice (schematic, diagnostic-only).

A.2.1 Visual Legend (Diagnostic Only)

This legend is descriptive only and refers exclusively to observable behavior.

Polar Lattice

- Center: reference oscillatory condition (visual origin only)
- Radius: harmonic order (inner = lower order, outer = higher order)
- Angle: phase orientation (rotation-invariant)

Vectors

- Direction:
  - Outward arrow: forward progression
  - Inward arrow: reverse progression
- Length:
  - Relative flux or emphasis
  - Comparative, not absolute
- Anchor:
  - Instantaneous harmonic location

Groupings

- Closed loop:
  - Persistent relational configuration
- Open or deforming loop:
  - Transitional configuration

Orientation-Reversing Marker

- Half-twisted loop:
  - Local inversion of directional consistency
  - Diagnostic marker only

Temporal Usage

- Single frame: snapshot
- Multiple frames: comparison
- Animation: progression

No element in this legend implies internal structure, mechanism, or control.

A.2.2 Coordinate System

The diagnostic field is represented on a polar grid.

- **Radial distance**
  Proportional to prime-ratio magnitude. Higher-order ratios appear farther from the center.
- **Angular position**
  Proportional to phase position within the rotational lattice.

The center of the diagram represents the reference oscillatory anchor.

A.2.3 Vector Notes

Notes are represented as **vectors**, not points.

Each vector has:

- **Length**
  Proportional to observable flux or intensity.
- **Direction**
  Indicates forward or reverse progression relative to the reference anchor.

This representation is descriptive only and carries no prescriptive meaning.

A.2.4 Grouping Glyphs

Groups of vectors may be encircled to indicate persistent relational structure.

- **Closed circle**
  Indicates a temporarily stable relational configuration.
- **Twisted loop**
  Indicates a transition region where reconfiguration is occurring.

These glyphs indicate behavior over time, not internal mechanism.

A.3 Alternate Renderings (Accessibility)

Accessibility is treated strictly as a **rendering problem**, not a control or modeling problem.

All alternate renderings project the *same observable behavior* into different output channels.

No alternate rendering introduces:

- new state,
- new inference,
- or new interpretation.

A.3.1 Auditory Rendering

Observable quantities may be rendered as sound parameters:

- **Amplitude** → proportional to flux magnitude
- **Pulse rate** → proportional to phase progression
- **Timbre class** → proportional to relational density

Auditory rendering is optional and diagnostic only.

A.3.2 Haptic Rendering

Observable quantities may be rendered as haptic signals:

- **Vibration intensity** → proportional to flux magnitude
- **Pulse rhythm** → proportional to phase progression
- **Envelope shape** → proportional to variability

No haptic signal feeds back into the system.

A.3.3 Textual / Event Rendering

Observable behavior may be logged or announced as discrete events:

- transitions,
- persistence intervals,
- threshold crossings.

Event text is factual and descriptive, not interpretive.

A.4 Channel Equivalence Principle

All renderings defined here are **channel-equivalent**:

- visual,
- auditory,
- haptic,
- textual.

They differ only in presentation, not in content.
The system does not depend on any single channel to be intelligible.

A.5 Boundary Statement

This appendix exists solely to support analysis and communication.
It does not:

- define mechanism,
- assert causation,
- imply experience,
- or assign meaning.

End of Appendix A.