

OPTIC-K: Symbolic–Spectral Embeddings for Musical Cognition

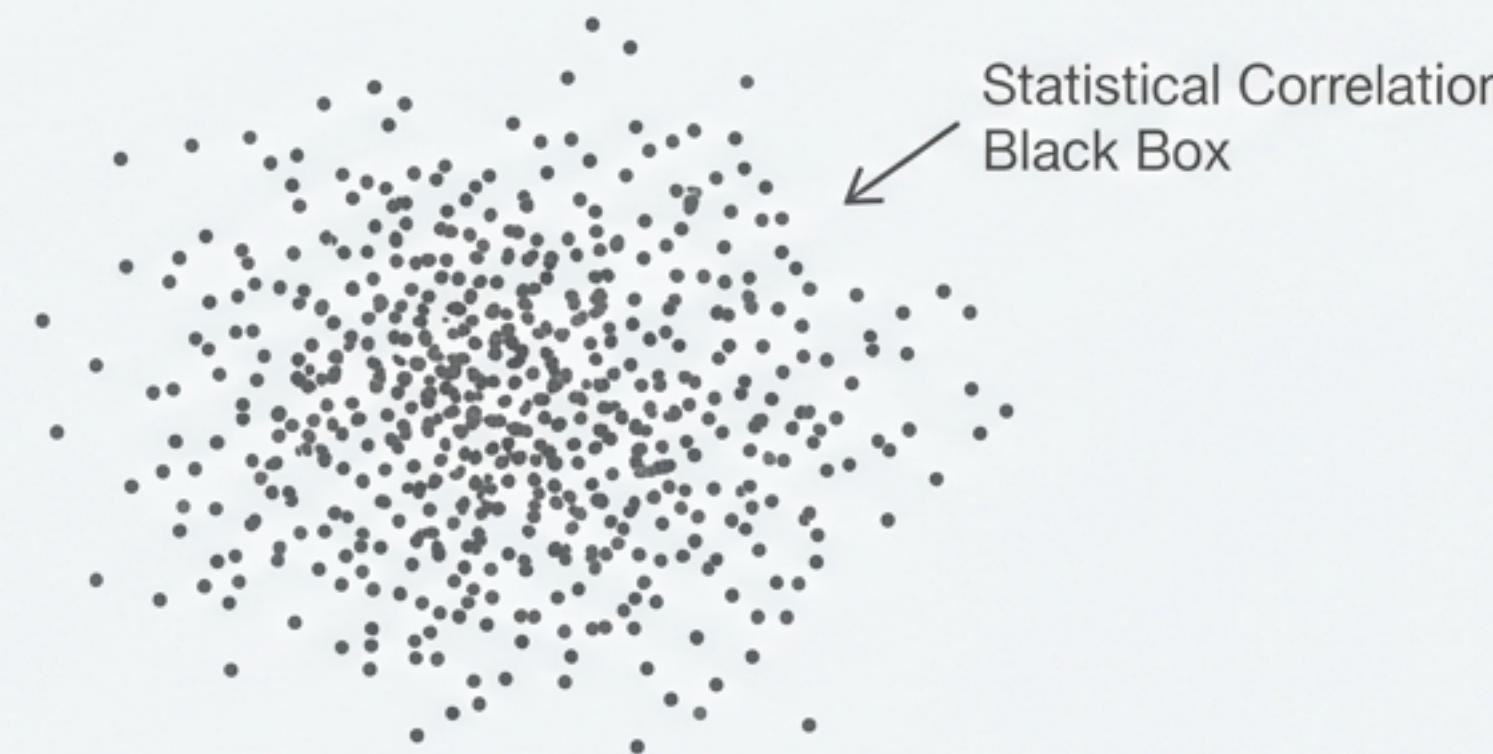
Beyond Feature Extraction: A Coordinate System for Harmonic Space

Music is geometry in time.

OPTIC-K is not a feature vector; it is a coordinate system.

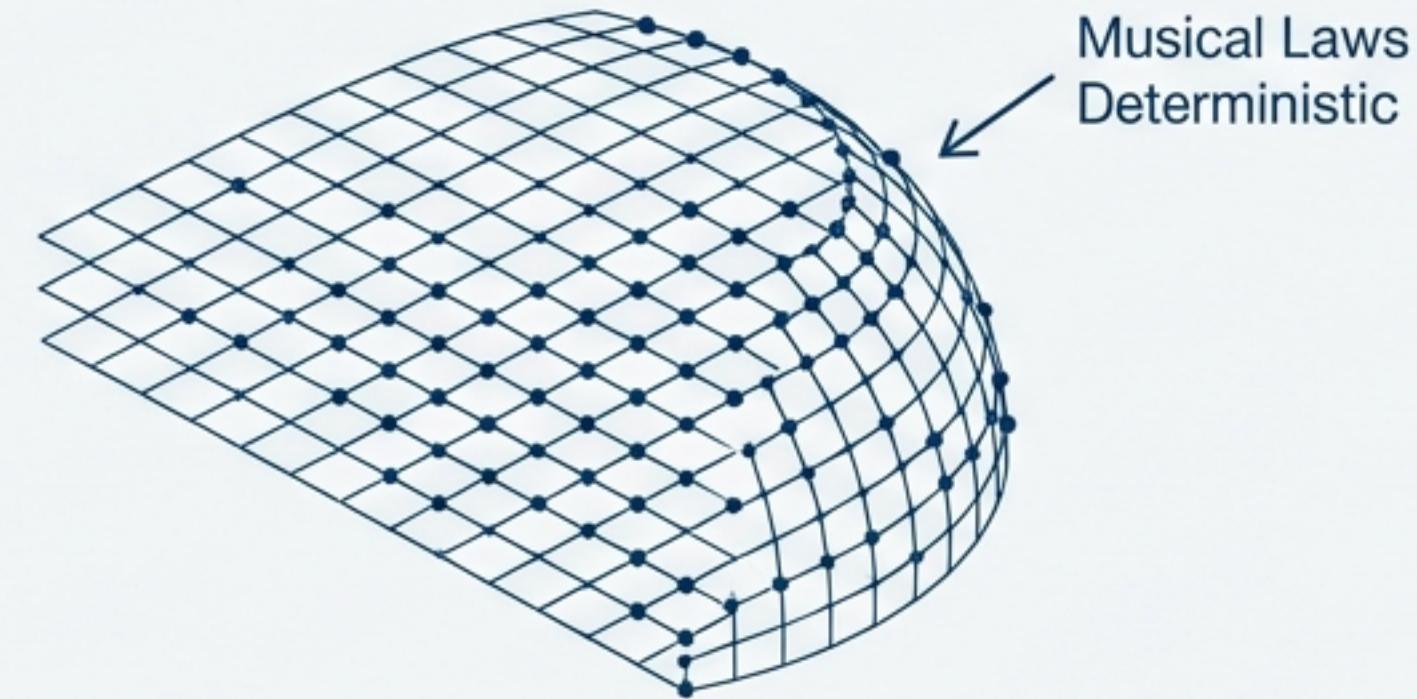
The Paradigm Shift

The Old Way: Neural Embeddings



Current models rely on pattern matching:
“These chords often appear together.” (Probabilistic)

The OPTIC-K Way: Geometric Cognition



OPTIC-K relies on harmonic physics:
“These chords are geometrically adjacent.” (Deterministic)

Core Truths

Similarity = Geometric Proximity (Geodesics)

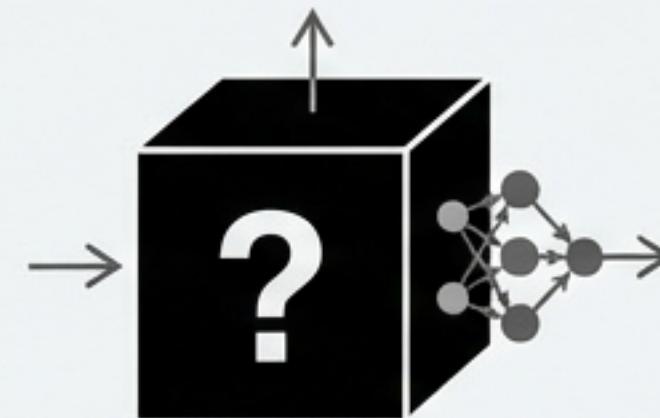
↗ **Modulation** = Spectral Rotation

↓ **Voice-leading** = Gradient Descent

Identity = 109-Dimensional Hybrid Manifold

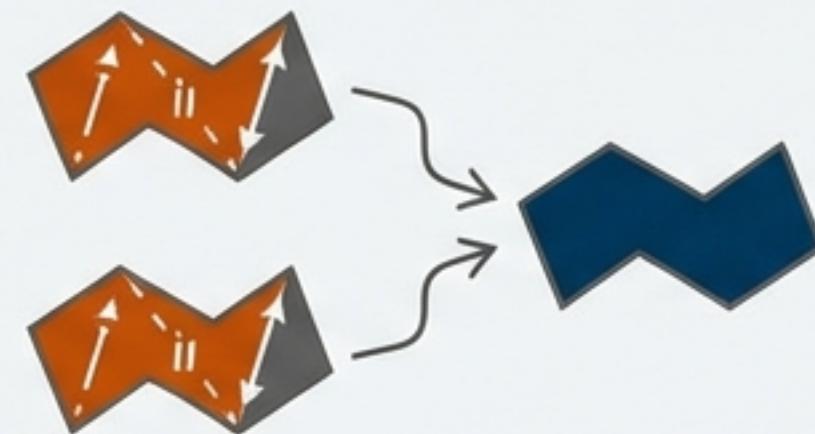
You cannot navigate without a map.

Why “Black Box” Neural Embeddings Fail at Music



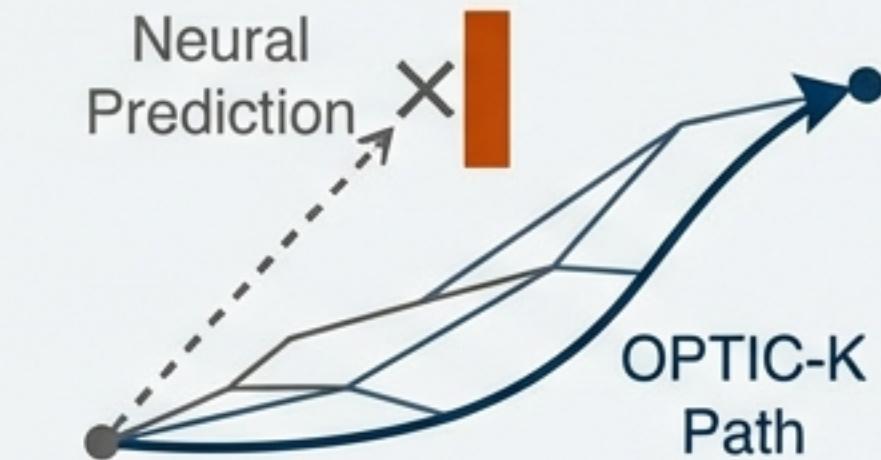
1. Opaque Logic

Neural vectors imply similarity based on training context but cannot explain why. OPTIC-K defines proximity via explicit interval structure and spectral phase.



2. The ‘Z-Relation’ Collapse

Neural embeddings treat Z-related sets (harmonic twins with identical intervals but opposite pulls) as the same object. OPTIC-K preserves their antipodal geometry.



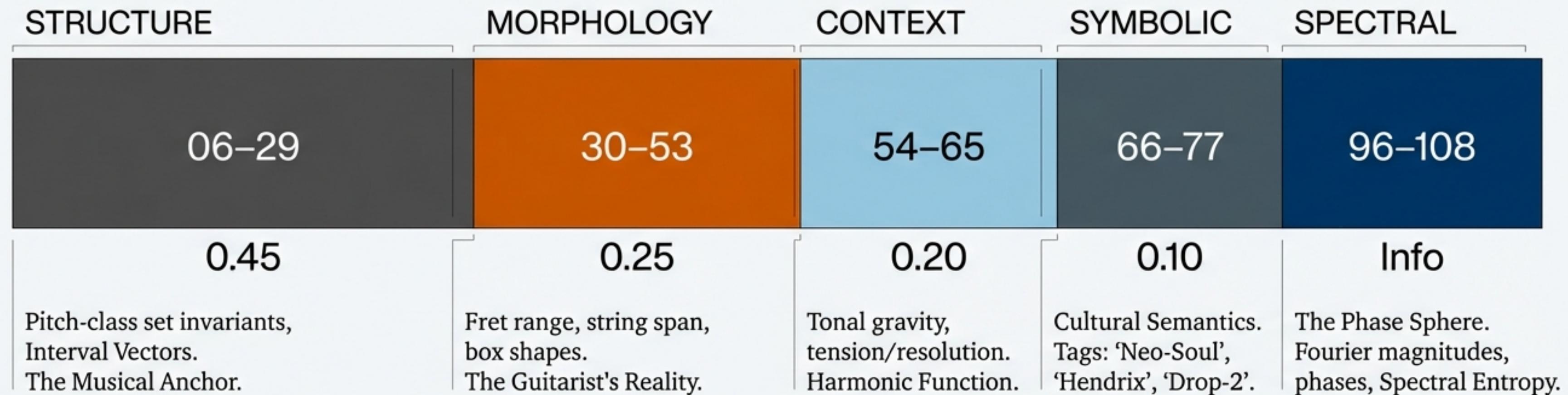
3. No Modulation Path

Neural systems predict the next likely chord but cannot compute the ‘smoothest’ path between distant keys. They lack the coordinate system to navigate.

**Bottom Line: Neural embeddings are statistical approximations.
OPTIC-K is a formal theory of harmonic space.**

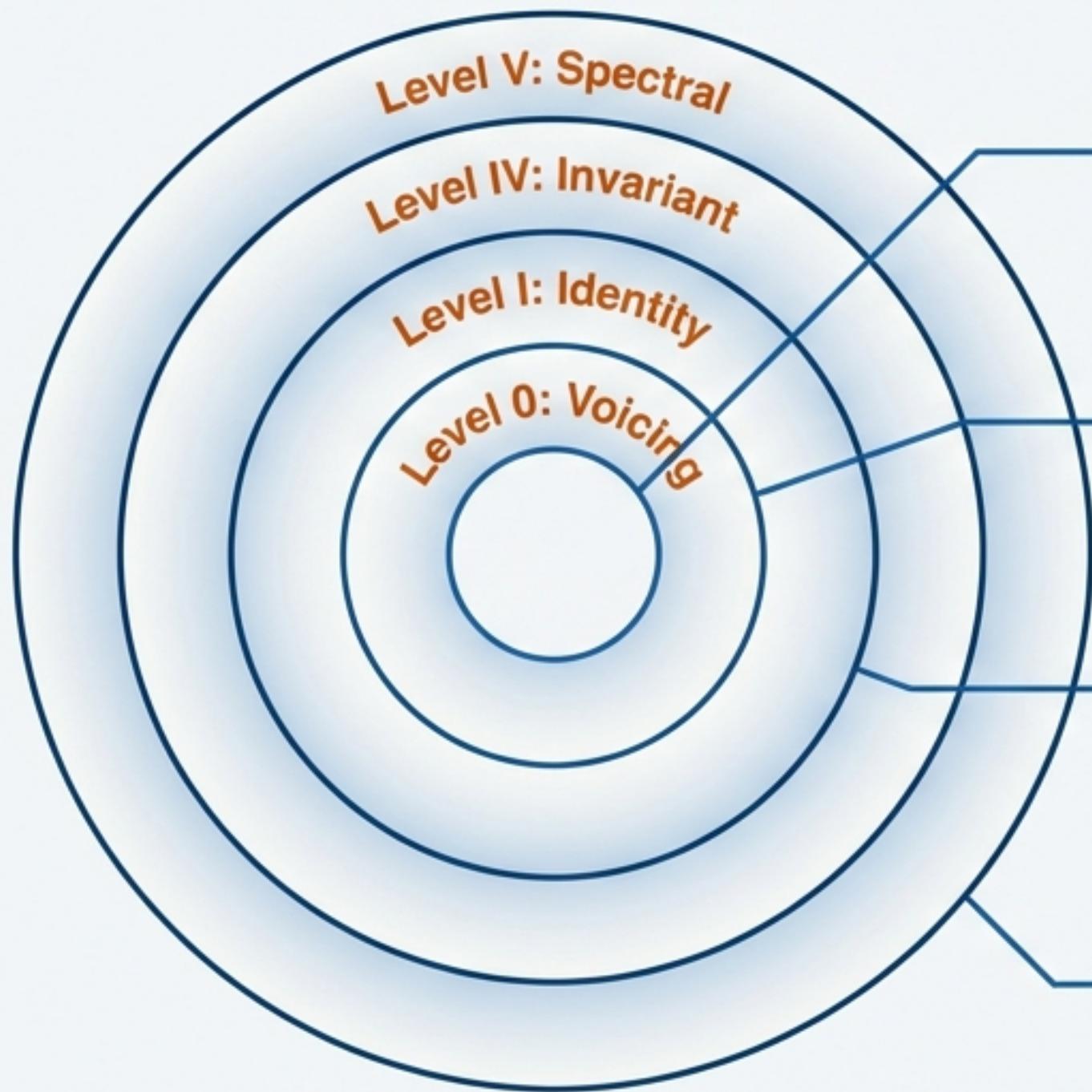
The 109-Dimensional Manifold

Anatomy of the Embedding Vector (v1.3.1)



The 'Onion' of Musical Identity

Decomposing a single object into constituent layers



Physical Instance: 'x-3-2-0-0-0' (Specific fretboard location)

Utility: Search here for 'Similar Shape' (Playability).

Musical Object: 'Cmaj7' (Root: C)

Deep DNA: Interval Vector $<101220>$
(1 semitone, 2 major thirds, 2 fifths)

Utility: Search here for 'Similar Sound'
(Substitutions like Em9/C).

Level V: Spectral

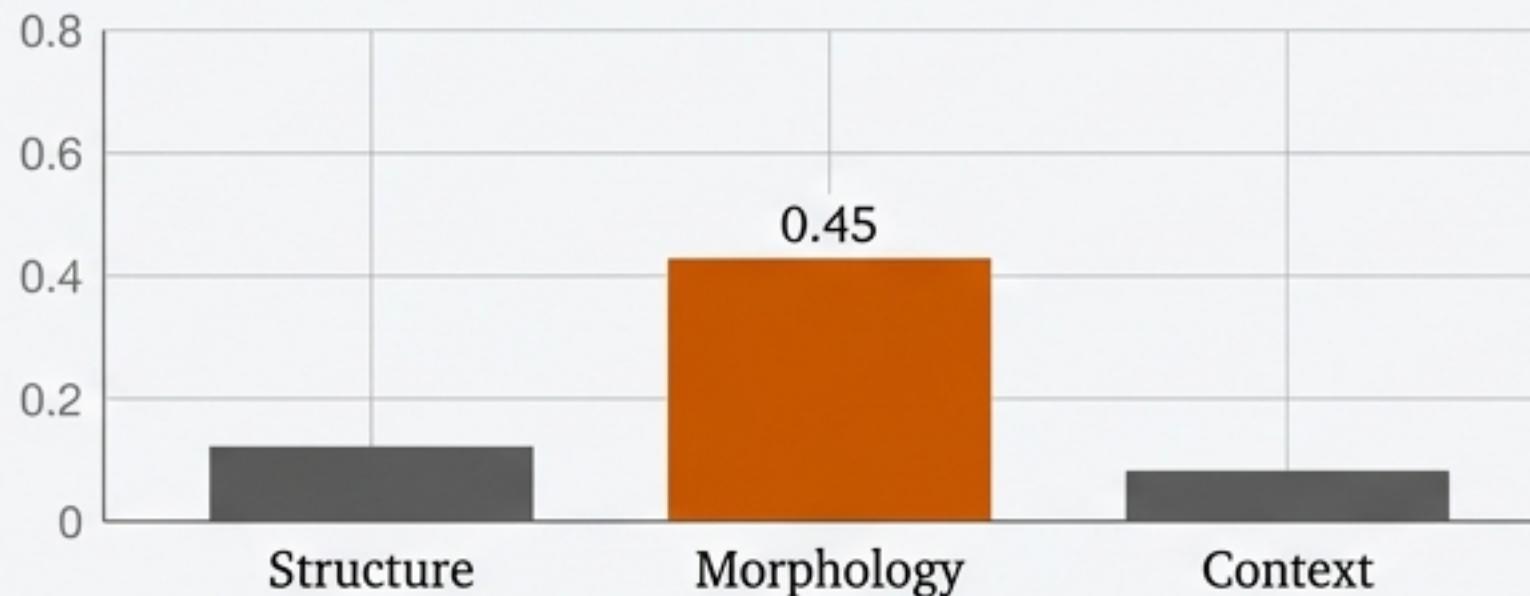
Geometry: A shape on the Circle of
Fifths.

The Logic of Similarity: Partitioned Cosine

Standard AI treats vectors as single blobs. OPTIC-K slices them to match musical intent.

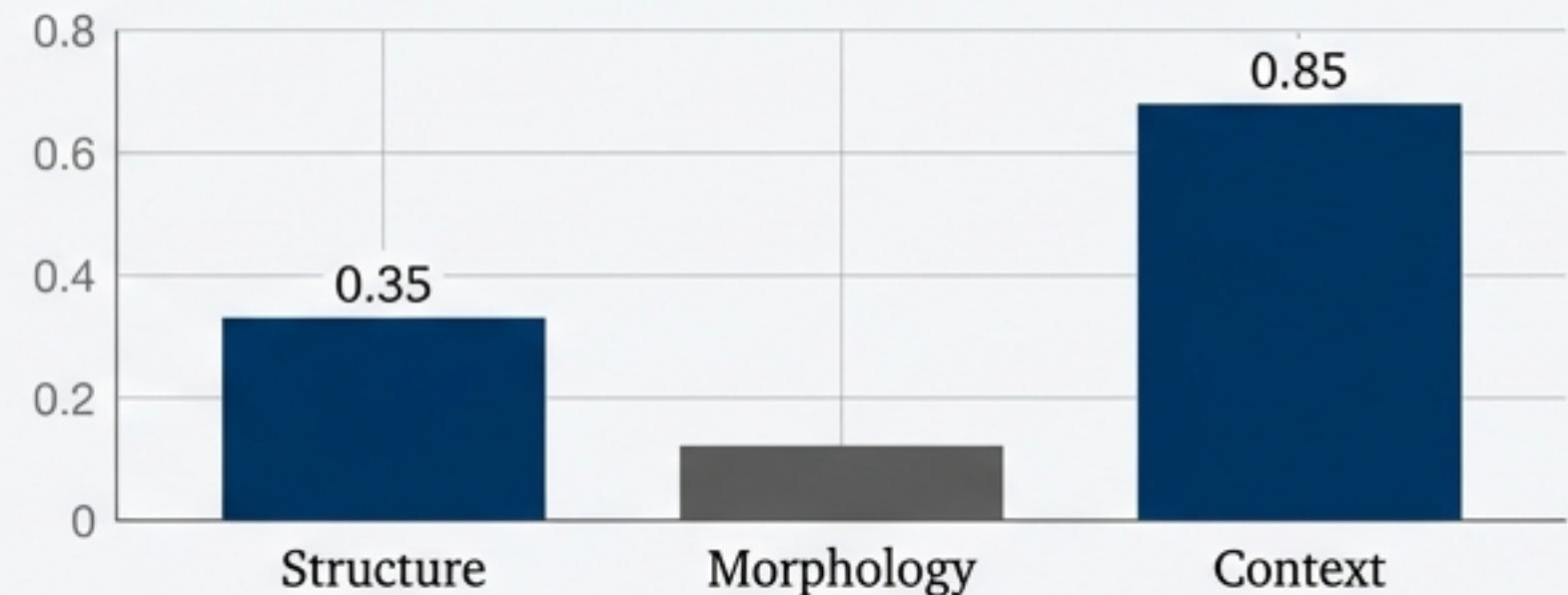
$$\text{Global Score} = (w_1 \times \text{Structure}) + (w_2 \times \text{Morphology}) + (w_3 \times \text{Context})$$

Scenario: “Find a Spread Voicing”



System prioritizes string span and physicality over exact note identity.

Scenario: “Find a Functional Substitute”



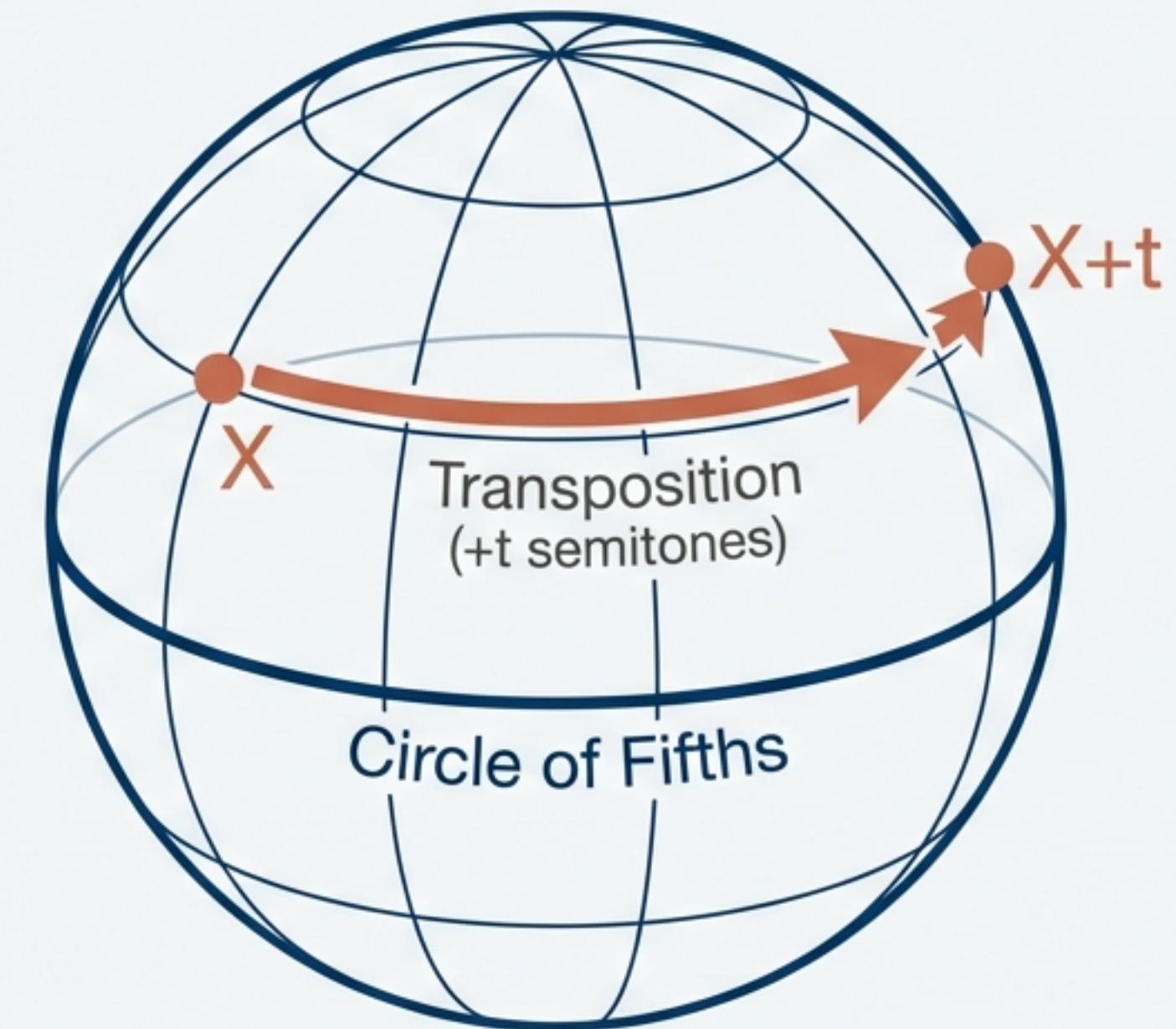
System finds chords that work mathematically, even if they look different on the fretboard.

The Phase Sphere: Fourier Space Geometry

Transposition is just Rotation.

Lewin's Lemma: The Interval Class Vector is the squared magnitude of the DFT.

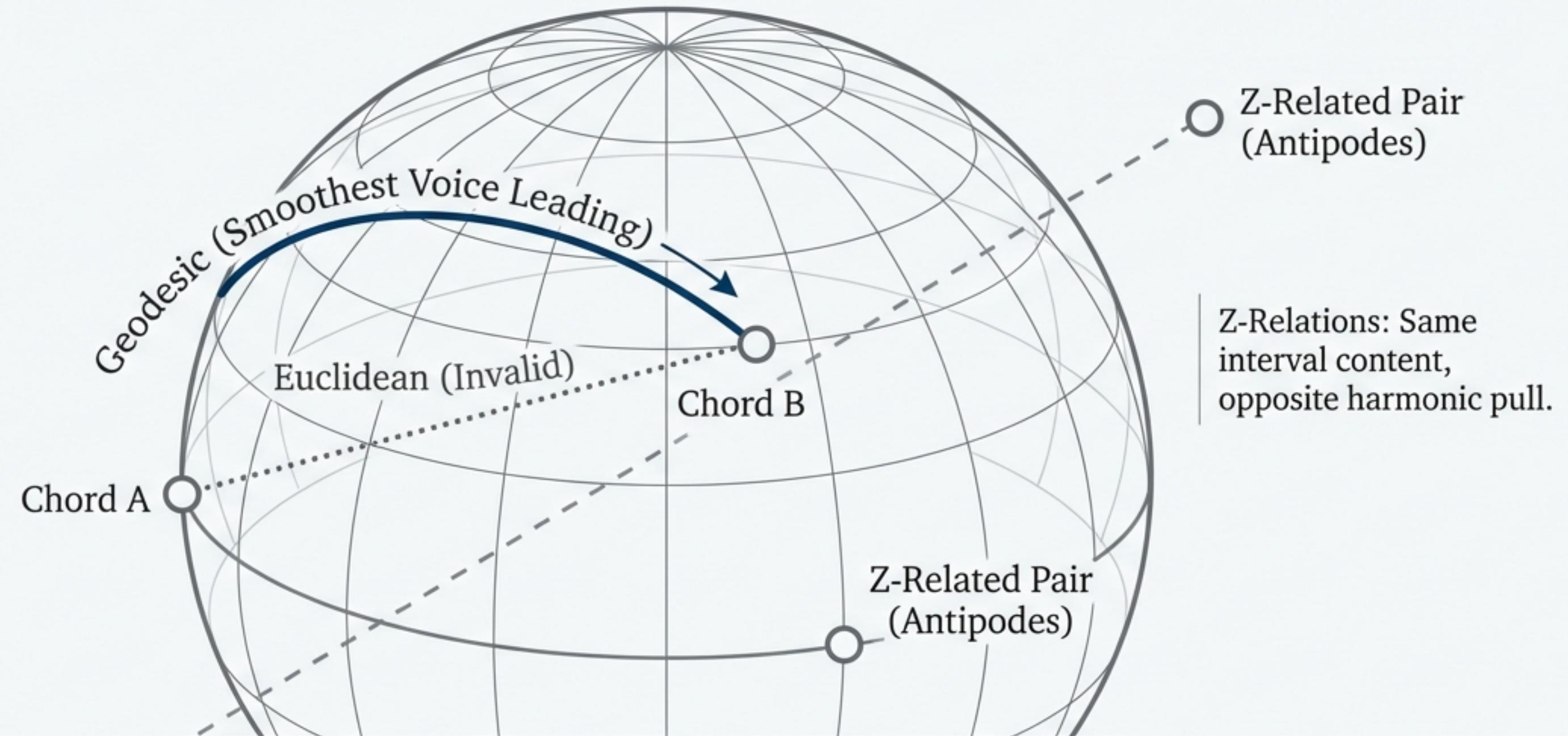
$$\mathbf{F}_k(\mathbf{X} + t) = e^{\frac{-2\pi i k t}{12}} \cdot \mathbf{F}_k(\mathbf{X})$$



The system doesn't need to “learn” 12 keys. Distance is simply the angle on the sphere.

Navigation & Geodesics

Voice-leading is the shortest path on the sphere.



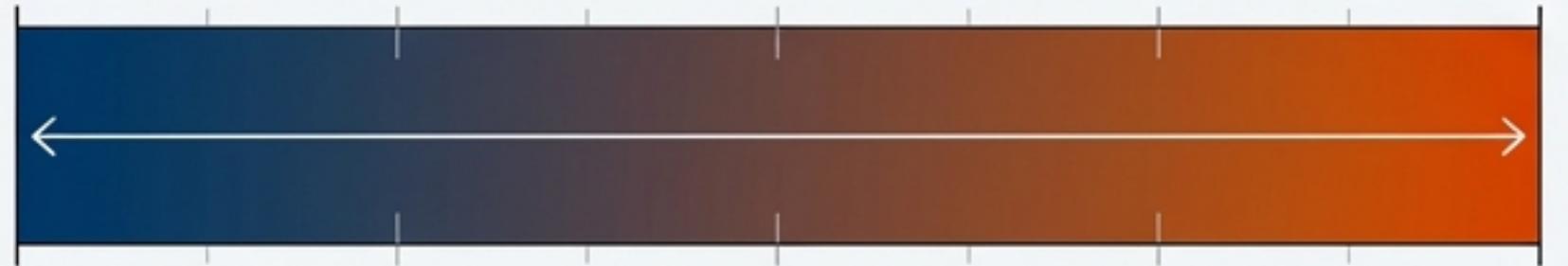
Application: Key-less Modulation. 1. Compute spectral positions. 2. Calculate geodesic arc. 3. Walk the path to find pivot chords.

Entropy, Gravity, and Curvature

Measuring the ‘Temperature’ and ‘Pull’ of harmony.

Spectral Entropy (Temperature)

Spectral Entropy
($\rightarrow 0$)



Low Entropy ($\rightarrow 0$)

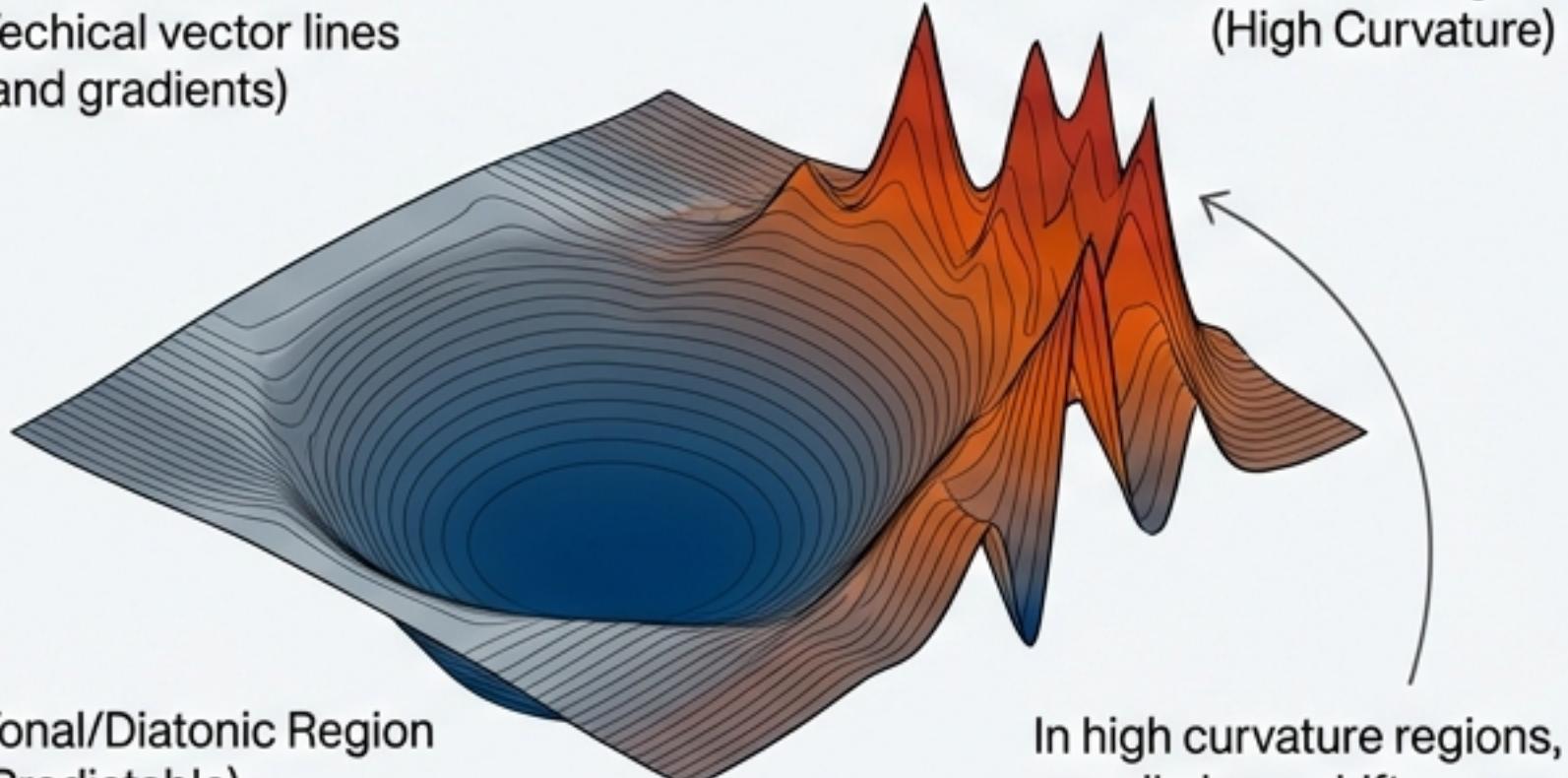
Diatonic, Organized,
Pure Cycles.
Stable.

High Entropy ($\rightarrow 1$)

Chromatic, Noisy,
Uniform Spectrum.
Volatile.

Spectral Curvature (The Manifold)

Technical vector lines
(and gradients)



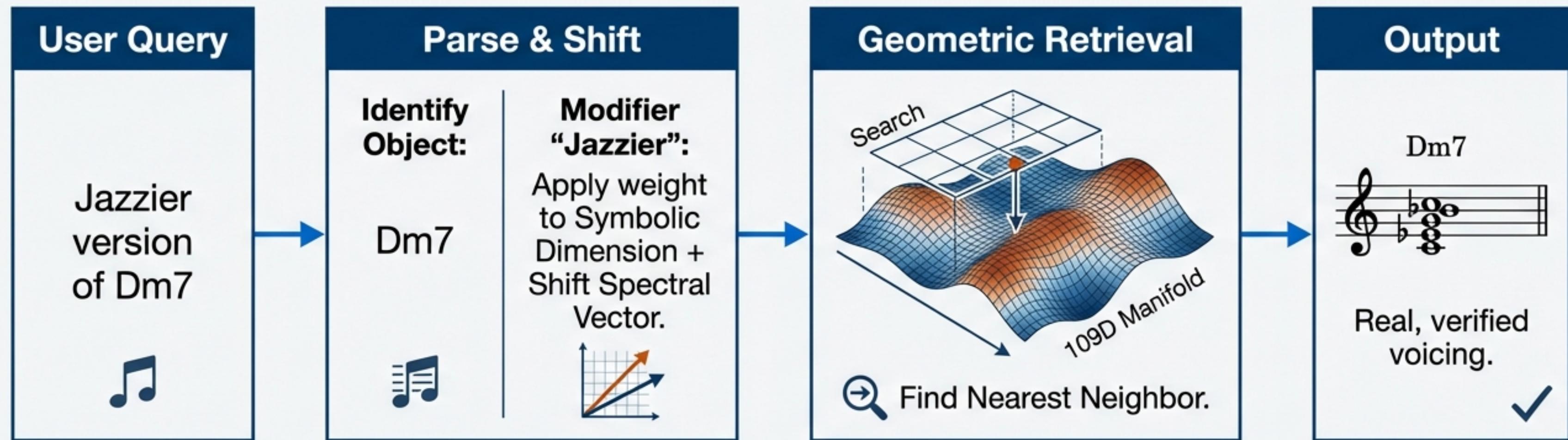
Tonal/Diatonic Region
(Predictable)

In high curvature regions,
small phase shifts cause
massive perceptual changes.

Barycenter: The calculated Center of Gravity for a progression.

Spectral RAG: Fixing the Music Bot

Solving the “Hallucination” problem with Geometric Retrieval.

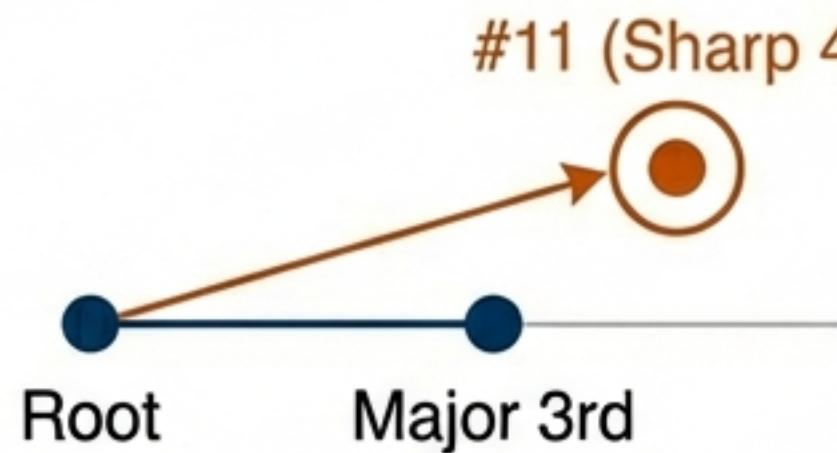


The LLM acts as the narrator; OPTIC-K provides the musical truth.

Production Feature: Modal Flavor Tagging

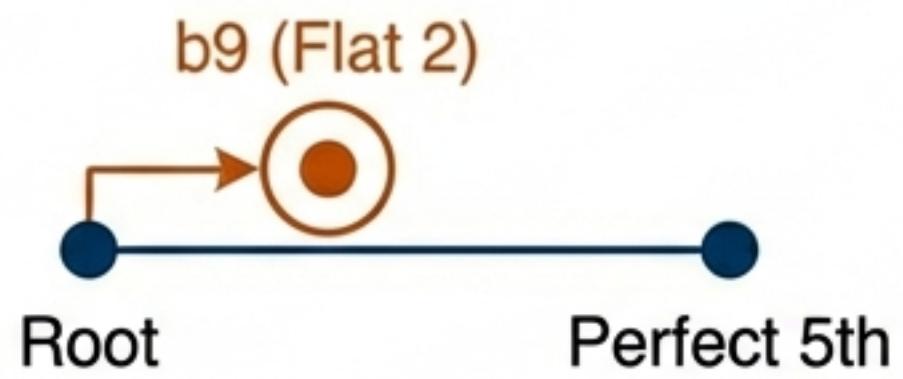
Enriching voicings by detecting ‘Characteristic Intervals’.

Lydian Flavor



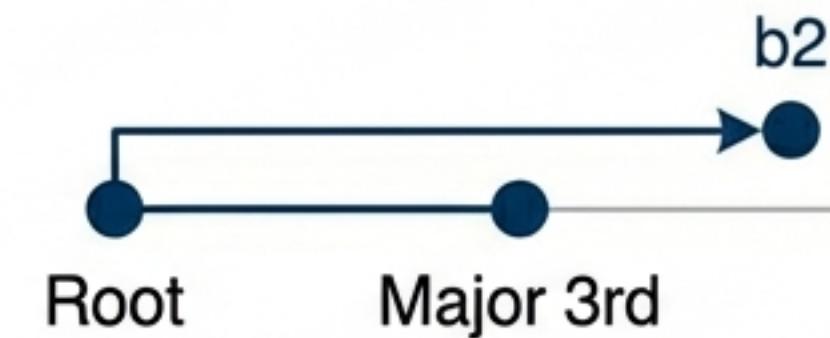
Dreamy / Film Score

Phrygian Flavor



Spanish / Tension

Phrygian Dominant

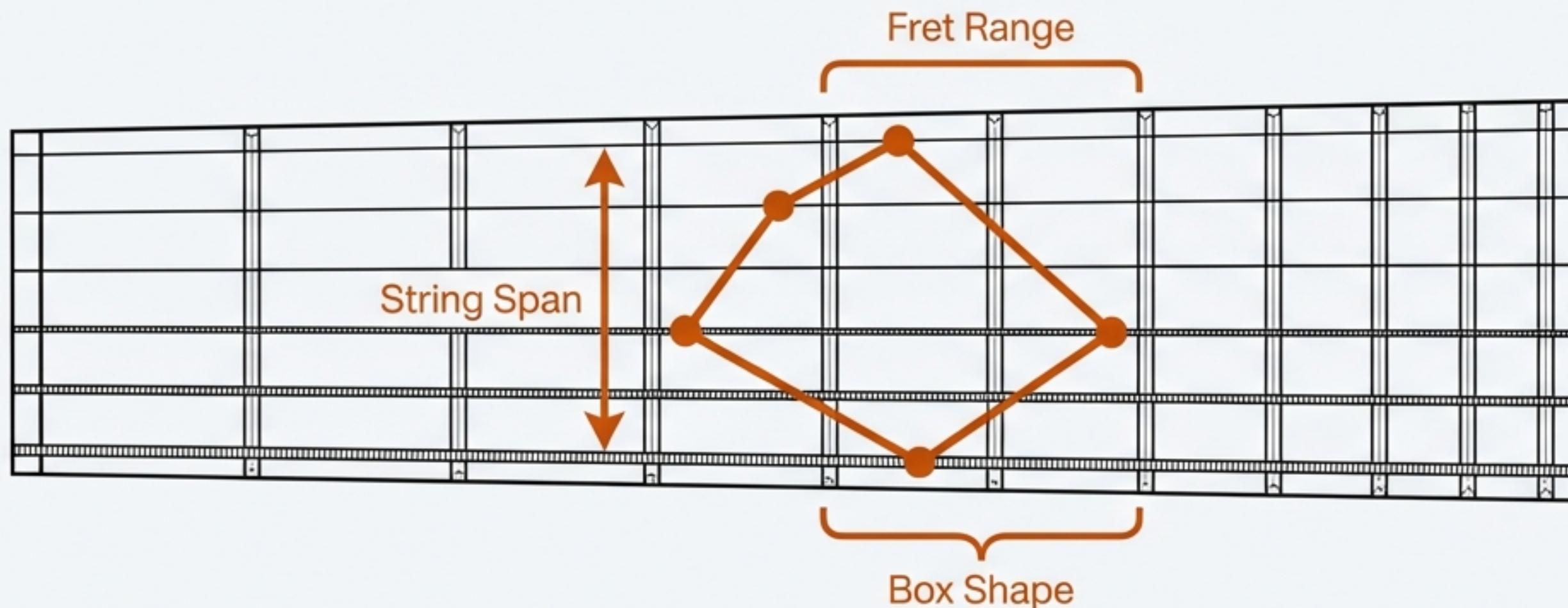


Flamenco / Exotic

Users search for ‘Dreamy’ or ‘Spanish’ and get mathematically verified results based on interval geometry.

Morphology: Geometry of the Fretboard

Ensuring playability with physical constraints.



Morphology Features (Indices 30-53)

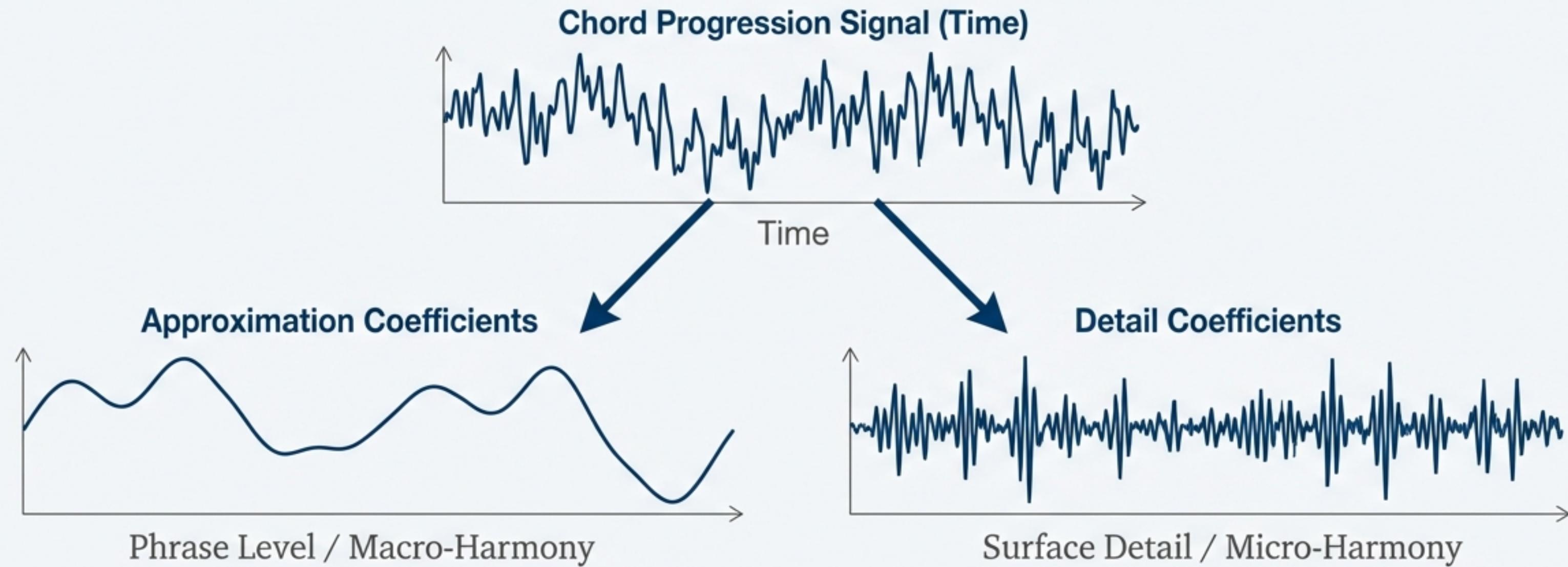
1. **Box Shapes**
(CAGED encoding)
2. **String Span**
(Vertical width)
3. **Smoothness Budget**
(Voice-leading potential)

A theoretical Cmaj7 is useless if it requires 6 fingers.

Morphology Weight (0.25) ensures results are physically reachable.

Time & Hierarchy: The Wavelet Extension (DWT)

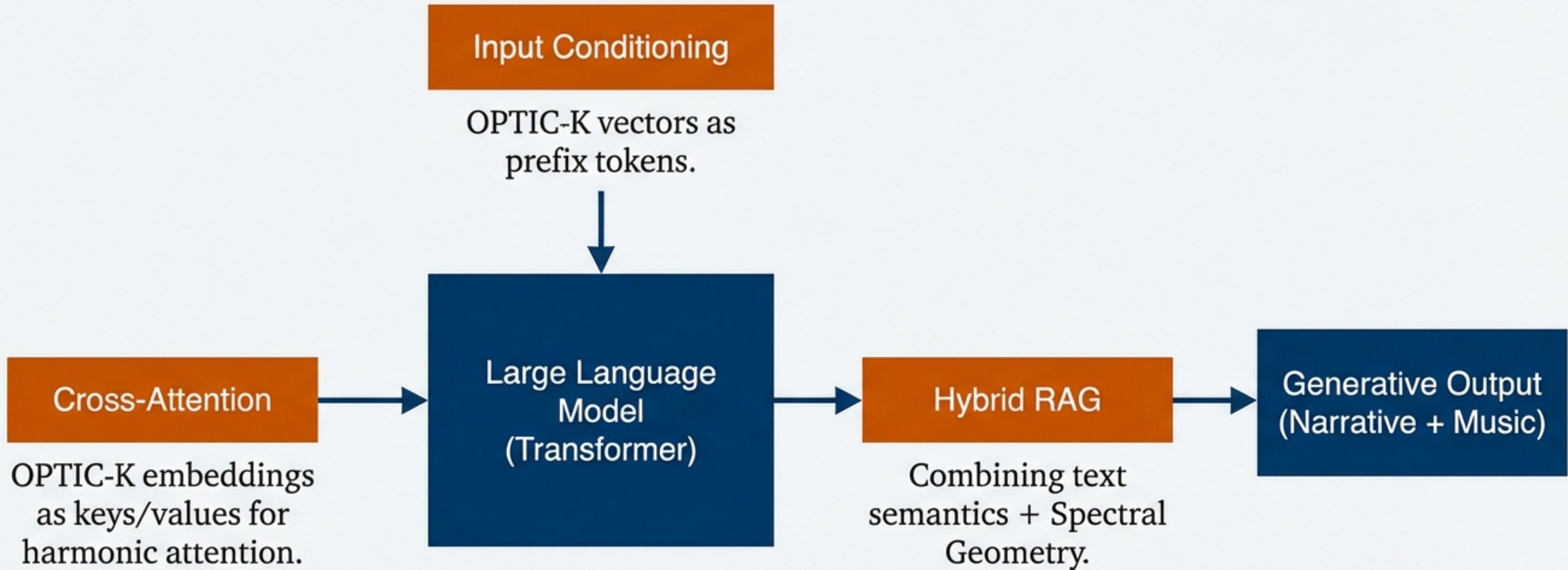
Moving from Static Objects (DFT) to Dynamic Signals.



The Innovation: Decomposing a chord progression into multi-resolution layers.
Allows detection of phrase boundaries and modeling of tension curves over time.

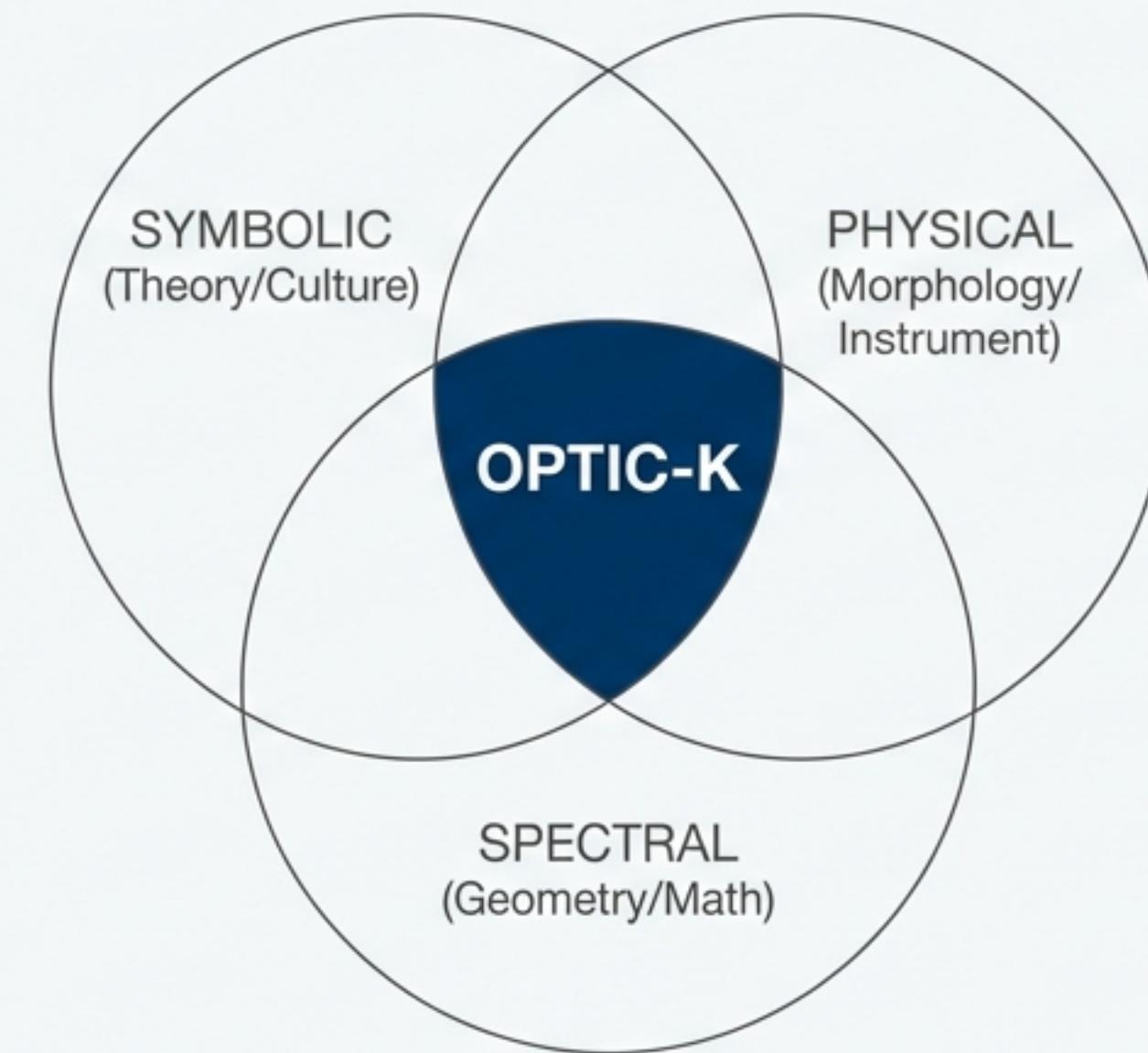
The Hybrid Architecture: Harmonic Cognition

Integration with the AI Ecosystem



Data Efficiency: Group Equivariance means the model learns 'Majorness' once, not 12 times.

A Unified Coordinate System



“You didn’t build a database. You built a musical coordinate system.”

OPTIC-K models the space where harmony actually lives.