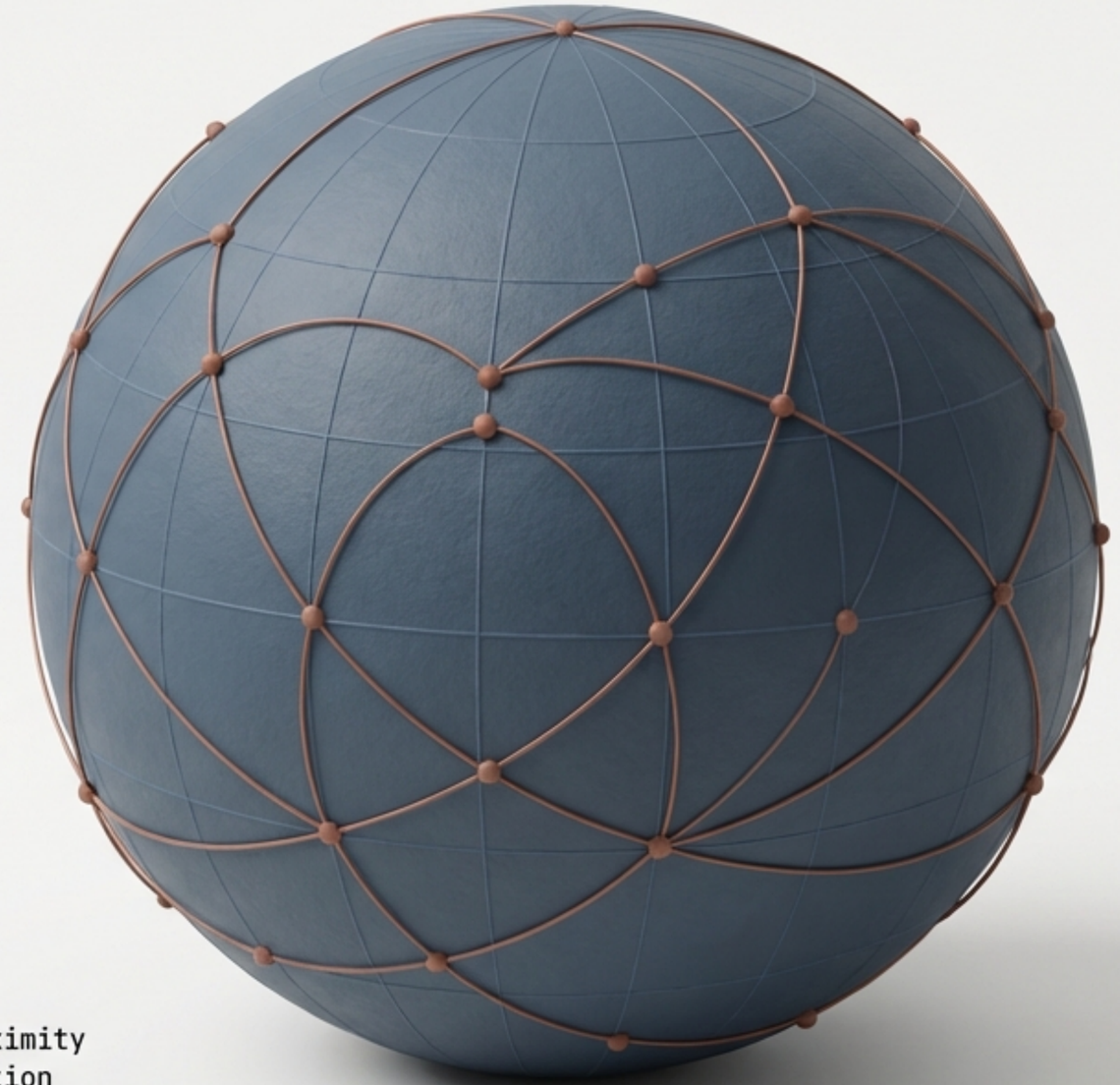
OPTIC-K: Symbolic–Spectral Embeddings for Musical Cognition

From Statistical Pattern Matching to Harmonic Geometry.



The Phase Sphere:
A navigable harmonic manifold.

OPTIC-K is not a feature vector. It is a coordinate system for musical objects. Current AI relies on neural embeddings that treat music as statistical "blobs." OPTIC-K embeds every chord, scale, and voicing into a 109-dimensional hybrid manifold.

```
// The Result:
> Similarity = Geometric Proximity
> Modulation = Spectral Rotation
> Voice-Leading = Geodesic Flow
> Transposition = Rotation
```

Music is Geometry in Time, Not Just Statistics

Neural Embeddings

Statistical & Opaque.

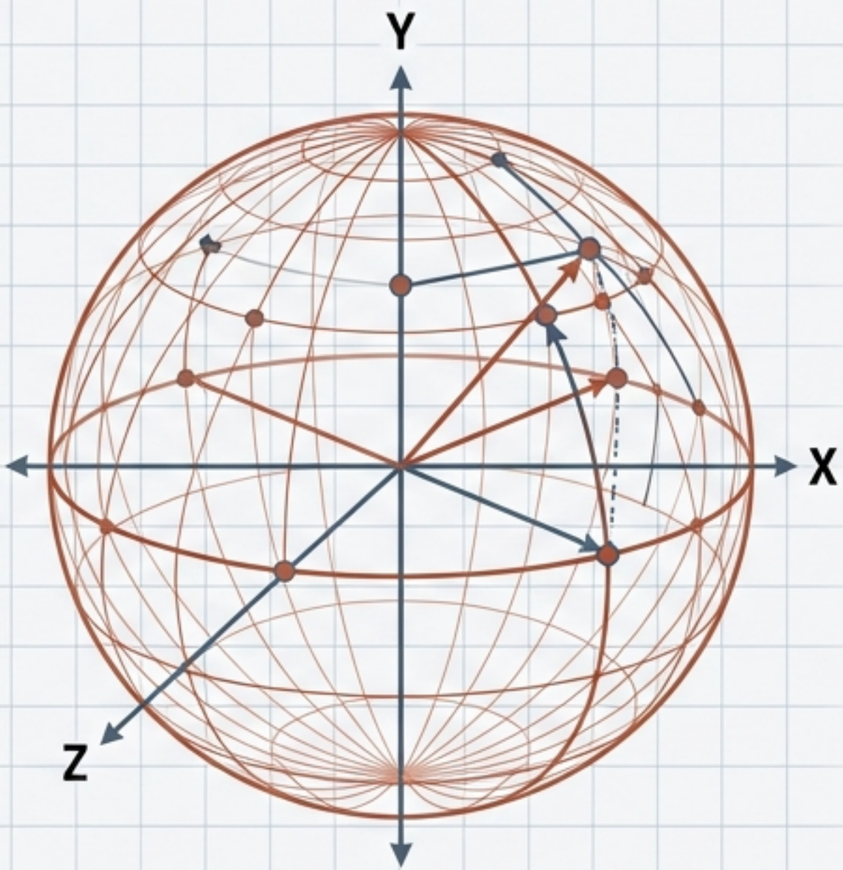
Learns correlations ('These appear together').

Cannot explain 'why'.

Collapses symmetry (confuses Z-relations).

Good for genre, fails at theory.

OPTIC-K Embeddings



Geometric & Interpretable.

Encodes musical laws ('These share a location').

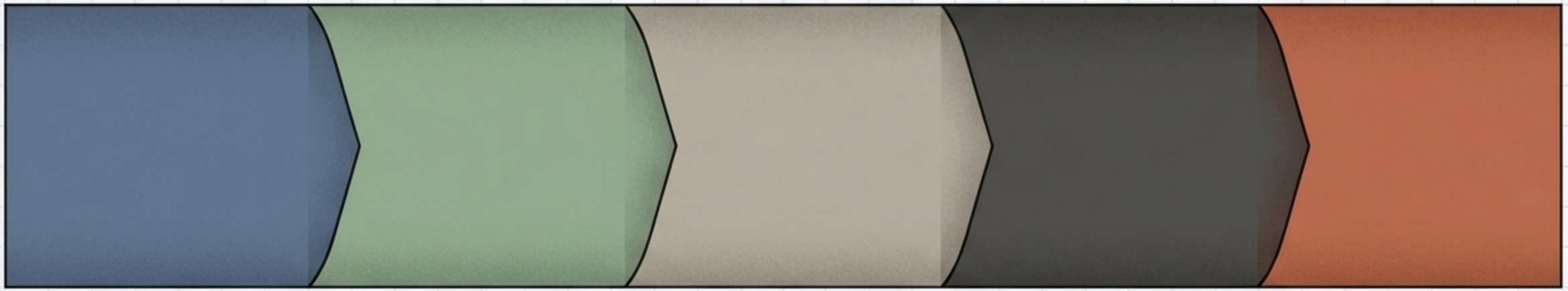
Fully explainable.

Preserves antipodal geometry.

Built for navigation and modulation.

Neural vectors lack structure. OPTIC-K provides a "Physics of Harmony" where every chord has a position, an orientation, and forces acting upon it.

The Architecture of the 109-Dimensional Manifold



Structure: Set-theoretic invariants. The ‘DNA” of the chord.

Physical: The guitarist’s reality. Fret range, span, box shapes.

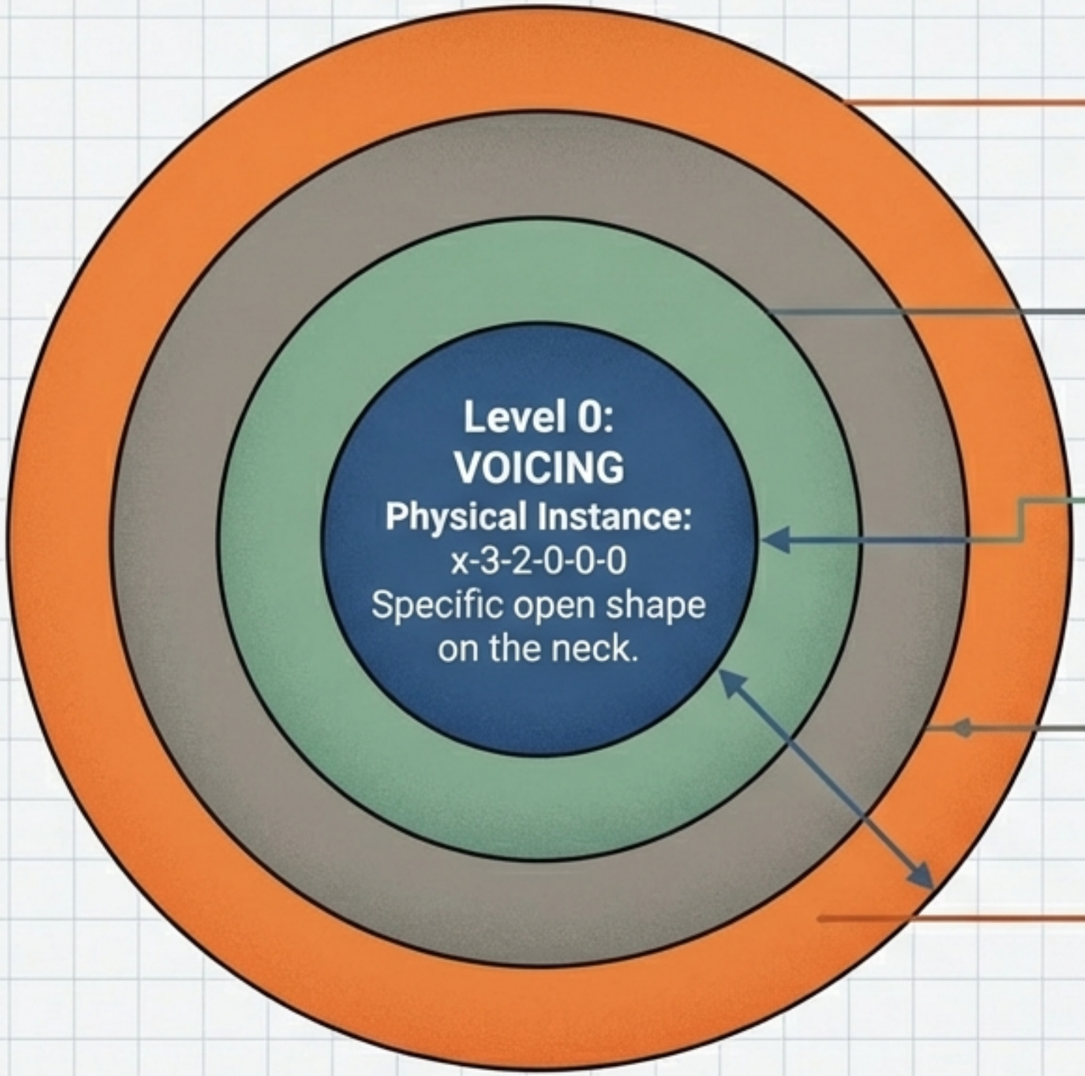
Function: Meaning & Tonal Gravity.

Technique: Style tags (e.g., ‘Neo-soul’) as dimensions.

Geometry: Fourier-space position on the Phase Sphere.

“A hybrid system that unifies symbolic, physical, and spectral meaning.”

Peeling the Onion: Decomposing Identity from Physics



Level V: SPECTRAL
Geometric Shape
Position on the harmonic manifold.

Level IV: INVARIANTS
Musical Ring: Cmaj7
any chacs the glown.

Level I: IDENTITY
Musical Object: Cmaj7
Any Cmaj7 chord, regardless of voicing.

Level IV: INVARIANTS
Interval Vector: <101220>
Deepest DNA structure.

Level V: SPECTRAL
Geometric Shape
Position on the harmonic manifold.

The Logic: Partitioned Cosine Cosine Similarity

Why partition?
A 'C Major Open' and 'C Major Shell' are musically identical (Structure = 1.0) but geometrically different (Morphology = 0.2).

A global cosine would fail here.

Partitioning allows us to weight of Structure over Shape.

"Moving from the physical 'how' to the abstract 'what' through hierarchical decomposition."

The Phase Sphere: A Manifold for Harmonic Space

Based on the **Discrete Fourier Transform (DFT)** of pitch-class sets.

Formula:

$$S(X) = (|F_1|e^{i\phi_1}, \ldots, |F_6|e^{i\phi_6})$$

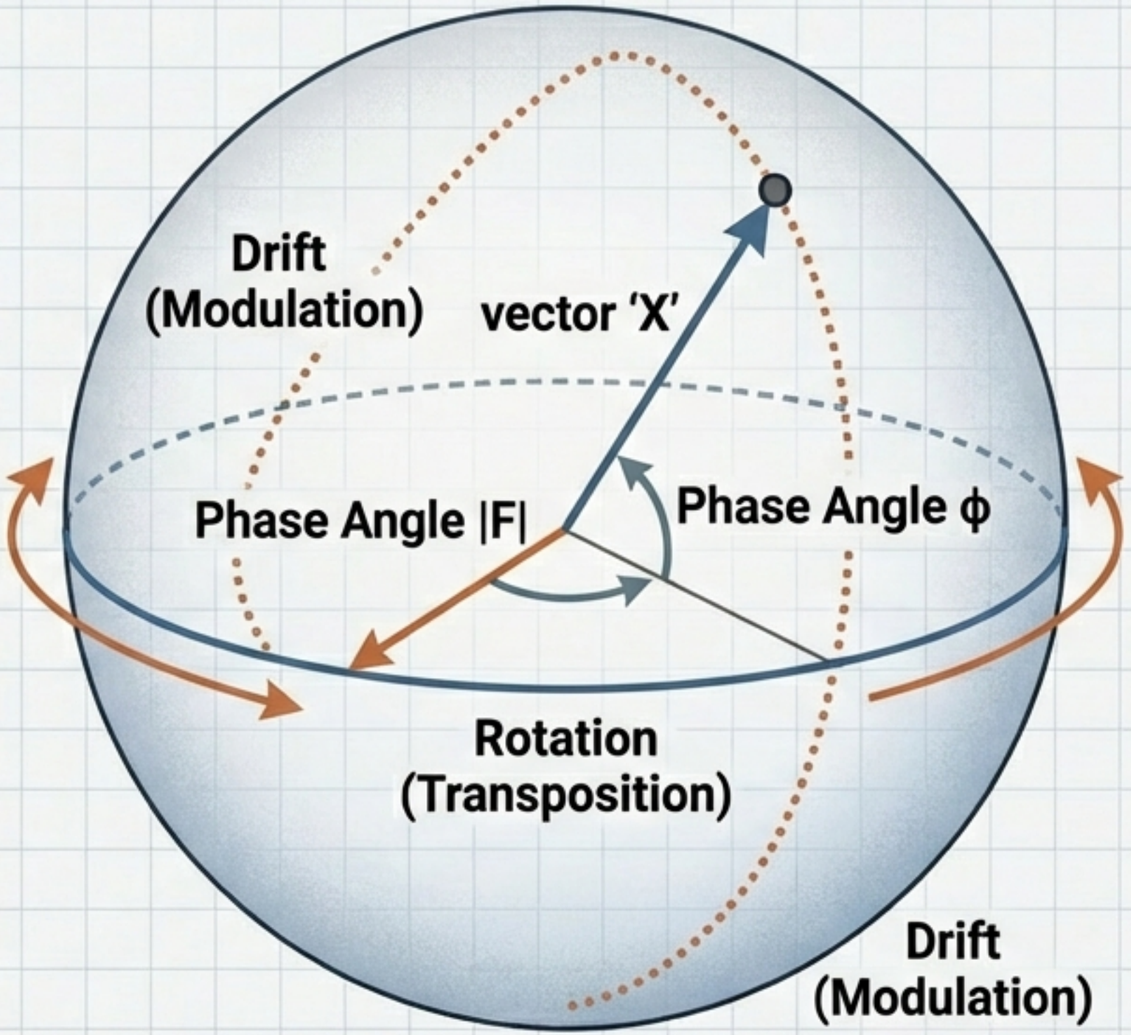
(Normalized to unit sphere).

Geometric Translation:

1. **Transposition is Rotation.**
Keys are just angles. Shifting a key rotates the phase ϕ without changing the magnitude structure.

2. **Modulation is Drift.**
Moving along the surface of the sphere.

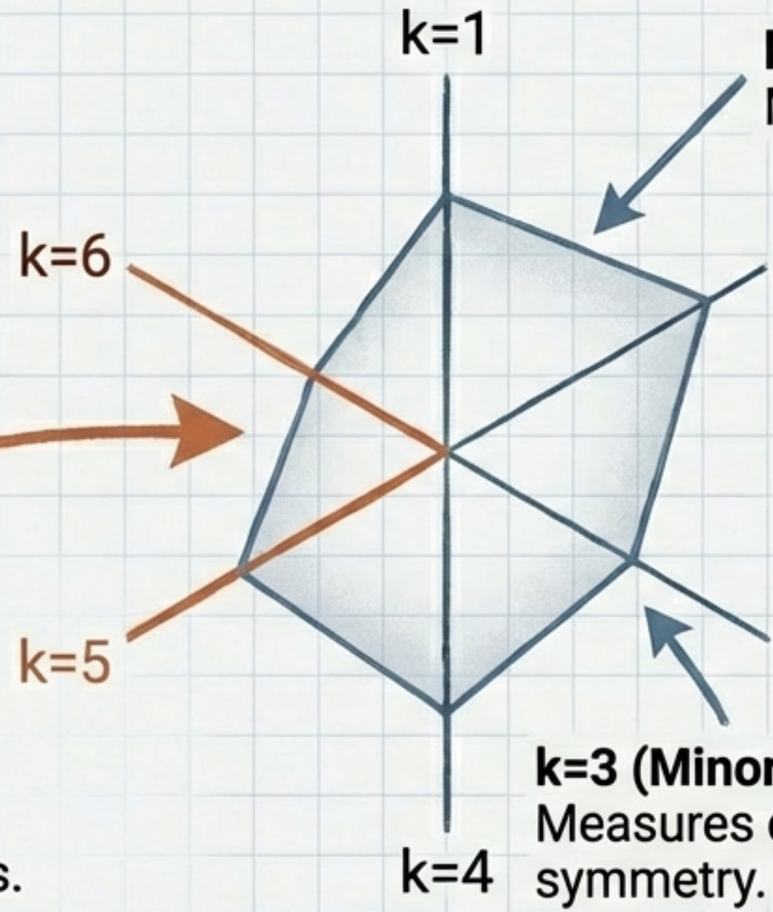
3. **Lewin's Lemma.**
Proves that Interval Class Vectors and Fourier Magnitudes are duals—the system is mathematically inevitable.



"Moving from the physical 'how' to the abstract 'what' through hierarchical decomposition."

Cycle Projections as Navigable Axes

The dimensions are not random. They are musical intervals that allow the AI to steer.



k=1 (Semitone Axis)
Measures chromatic clumping.

k=5 (Fifths Axis)
The "Key-ness" Axis.
Measures diatonic alignment and tonal gravity.
High value = Diatonic/Tonal.
Low value = Atonal/Ambiguous.

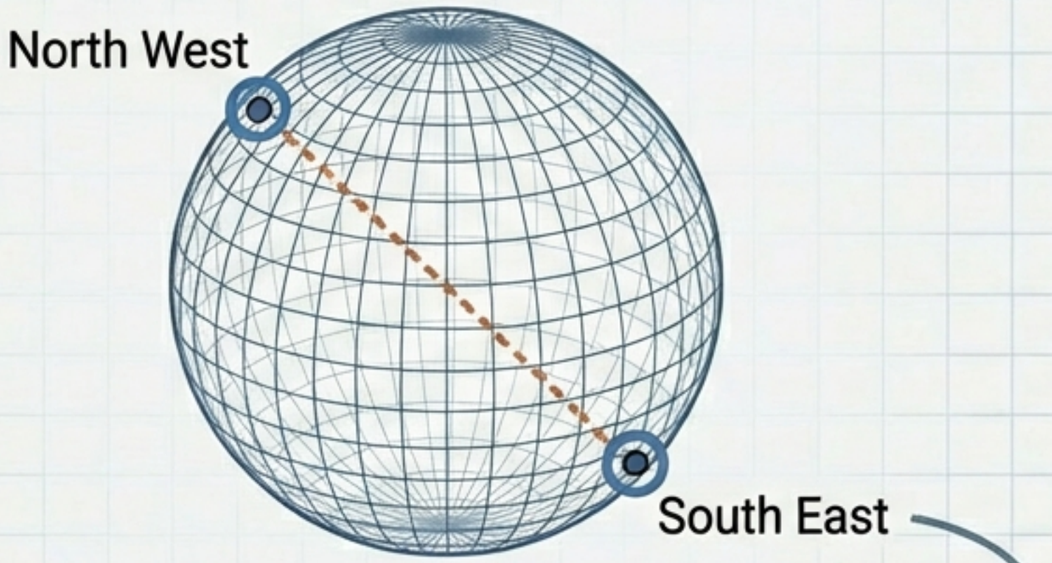
k=3 (Minor-Third Axis)
Measures diminished symmetry.

Navigation Strategy:
The AI can be directed to move "towards the fifths axis" (more tonal) or "away from the poles" (more ambiguous).

"Moving from the physical 'how' to the abstract 'what' through hierarchical decomposition."

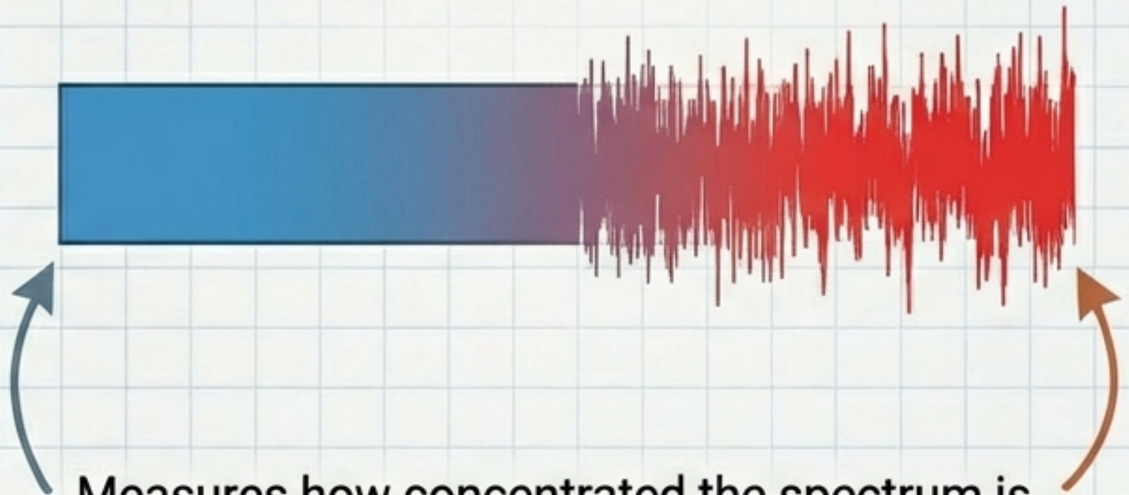
Encoding Tension, Ambiguity, and Symmetry

Z-Relations
(Harmonic Twins)



- Chords with identical interval content but different structures.
- Geometry: Antipodal symmetry (Same latitude, opposite longitude).
- Musicality: Same complexity, opposite harmonic pull. Ideal for 'Shadow Harmonies."

Spectral Entropy
(Harmonic Temperature)



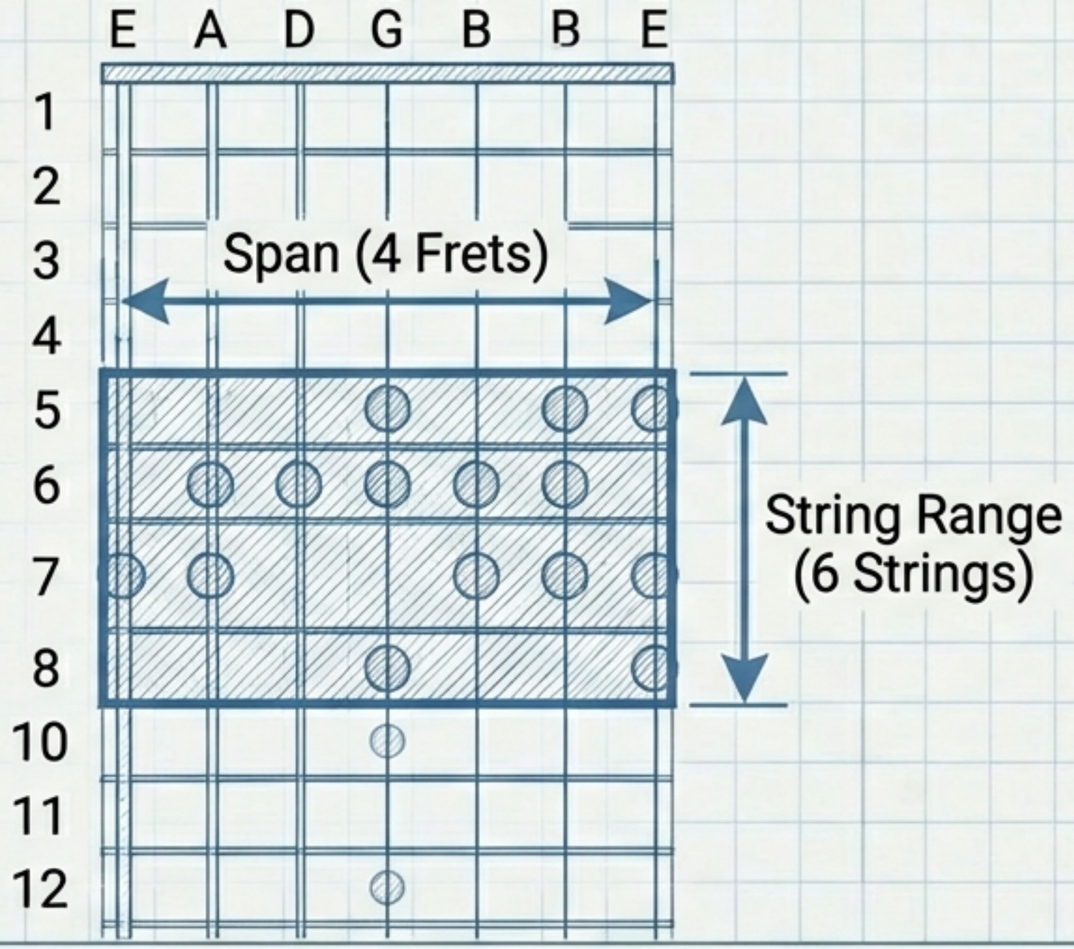
Measures how concentrated the spectrum is.

- **Low Entropy (~0.0)**: Diatonic, Pure, "Flat Curvature" (Stable).
- **High Entropy (~1.0)**: Chromatic, Noisy, "High Curvature" (Volatile).

"Moving from the physical 'how' to the abstract 'what' through hierarchical decomposition."

Morphology: The Guitarist's Physical Reality

A chord can be mathematically perfect but physically impossible.
Indices 49-53 encode "Box Shape Geometry" to solve this.



Encoded Metrics:

- **String Box Type**: 2-string vs 5-string shapes.
- **Contiguity**: Are strings adjacent or skipped?
- **CAGED Shape**: Explicit encoding of standard pedagogy.
- **Texture**: Brightness (Mean Register), Thickness (Doubling Ratio), Grip (Clustering).

"Moving from the physical 'how' to the abstract 'what' through hierarchical decomposition."

Spectral RAG: Solving Hallucination with Geometry

The Old Way: Text RAG

Query: "Jazzier version of Dm7"

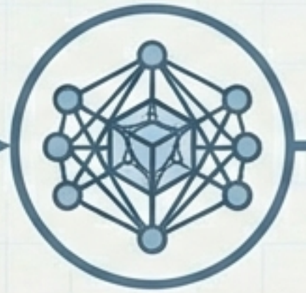
Document Search

Result: Generic article about Jazz theory.

Fails because "Jazzier" is not a keyword, it is a spectral quality.

The New Way: Spectral RAG

Query: "Jazzier version of Dm7"



OPTIC-K Engine

Mechanism: Retrieve vector geometrically close to Dm7 (Structure)
+ High Weight on Symbolic[Jazz]
+ High Extensions[Complexity].

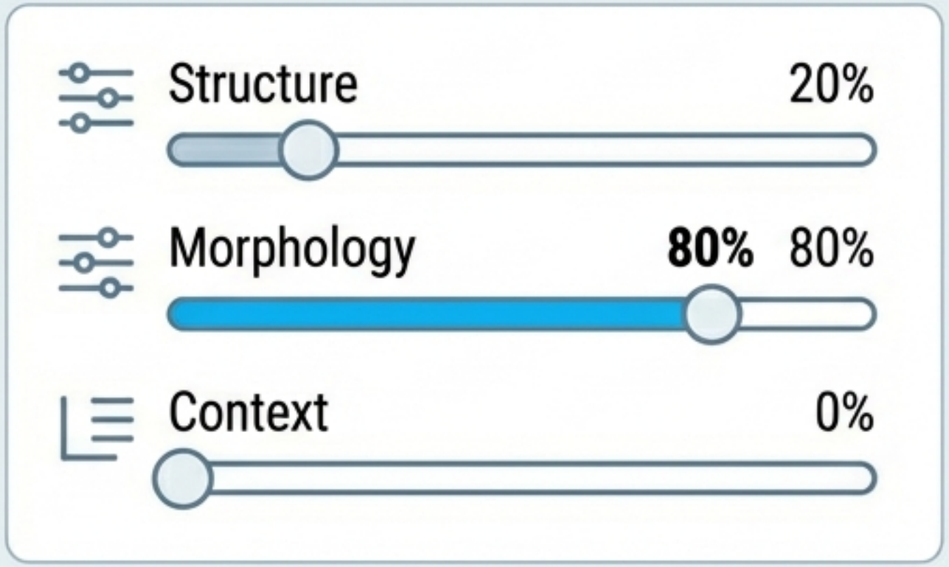
Result: Actual playable voicings (e.g., Dm11 drop-2).

The LLM becomes a narrator; OPTIC-K provides the musical truth.

Intelligent Querying: Dynamic Weighting

State A: Left Side

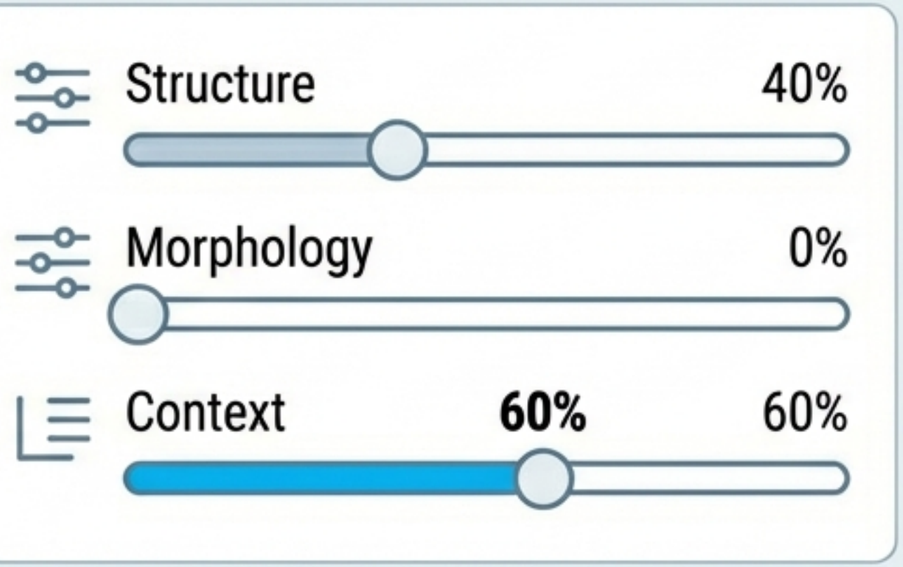
User Intent: “Find a similar physical shape”



Returns acoustically different chords that feel the same under the fingers.

State B: Right Side

User Intent: “Find a functional substitute”



Returns chords that sound different but serve the same function (e.g., Tritone subs).

Production Preset Note: Default Production Preset: [0.45 Structure, 0.25 Morphology, 0.20 Context, 0.10 Symbolic]

Production-Grade Voice Leading

Computing Geodesics in Harmonic Space

Spectral Distance:
The angle θ on the sphere predicts the smoothness of transition and modulation effort.

Key-less Modulation:
Neural models ask: "What usually follows X?" (Statistical).
OPTIC-K asks: "What is the shortest geometric path to Y?" (Geodesic).
This enables smooth interpolation between distant keys without distinct rules.

Production Preset Note: Default Production Preset: [0.45 Structure, 0.25 Morphology, 0.20 Context, 0.10 Symbolic]

Interpretation & Explainability (NLG)

The "Why" Behind the Recommendation.

Transcript

[User Icon]
Why did you recommend this chord?

[AI Icon]
This is a mid-register drop-2 voicing of Cmaj7.

1. **Structure:** It retains the essential Cmaj7 intervals.
2. **Texture:** Its high smoothness budget suggests good voice-leading.
3. **Geometry:** It is located on the fifths axis near the diatonic pole, ensuring stability.

Sidebar Analysis:

Mechanism: VoicingExplanationService

Reverse-maps embedding dimensions to Natural Language.

Explains Structure, Texture, and Theory.

No "Black Box" decisions.

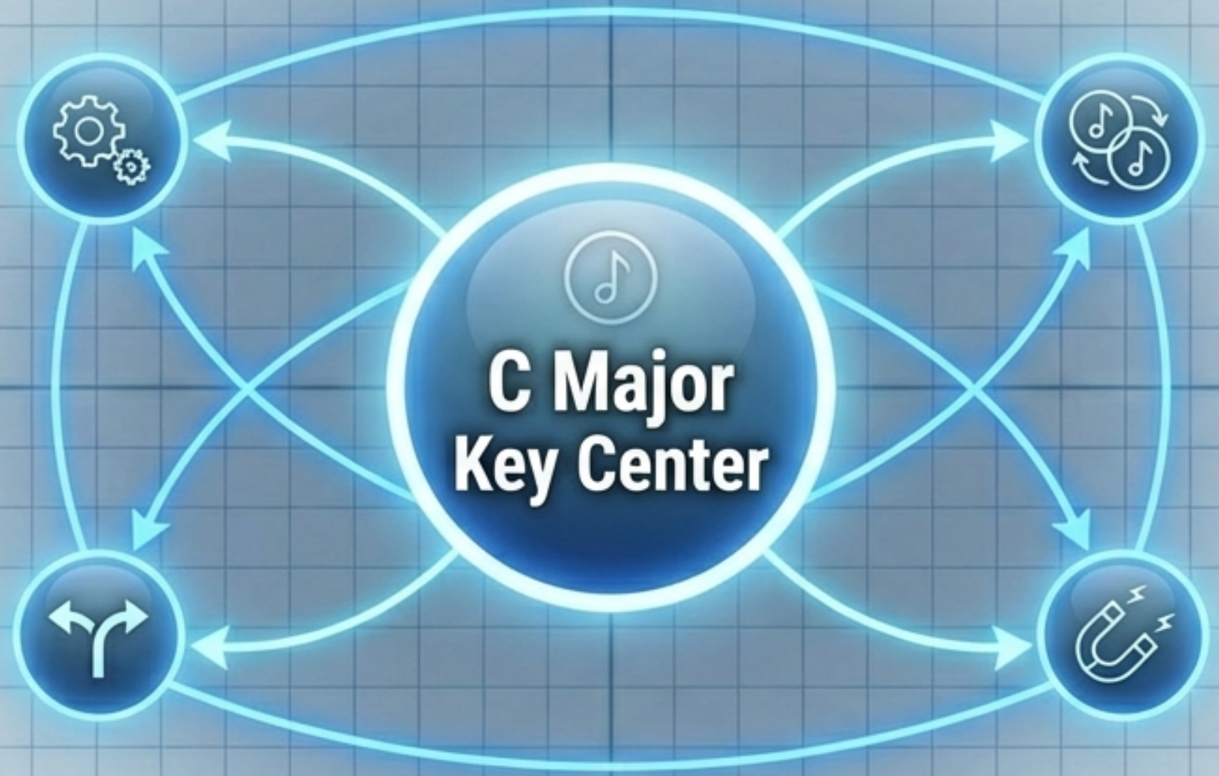
Production Preset Note: Default Production Preset: [0.45 Structure, 0.25 Morphology, 0.20 Context, 0.10 Symbolic]

Roadmap v1.4: From Objects to Relationships

Moving beyond isolated chords to Harmonic Context. New Indices: 109-121.

Secondary Dominants
Identifying V/V vs. V.

Modal Interchange
Identifying borrowed chords (e.g., iv from Minor).



Pivot Chords
Identifying chords that function in two keys simultaneously.

Tonal Gravity
Measuring the “pull” toward a tonic center.

Enables relational queries: “Find a pivot chord between C and G.”

Production Preset Note: Default Production Preset: [0.45 Structure, 0.25 Morphology, 0.20 Context, 0.10 Symbolic]

A Mathematical Layer for Modern AI Architectures

OPTIC-K Embeddings
(109-Dimensional Vector)

Integration

Transformers
Prefix Tokens (Conditioning) or Cross-Attention Keys.

Vector Databases
MongoDB, Pinecone, Qdrant.

Harmonic Cognition
Differentiable for Gradient Descent.

Efficiency: Learn harmony once (Group Equivariance), generalize to all 12 keys. Drastically reduces data requirements compared to neural training.

The Harmonic Cognition Engine

Navigating the space where harmony actually lives.

Neural Embeddings
Pattern Matching.
Approximate Similarity.

OPTIC-K
Geometry.
Exact Cognition.

Neural models approximate where things belong. OPTIC-K models the space where they live.