Real-Time Fractional Tracking (R-TFT): Dimensional Memory via Resonance-Indexed Embedding

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Abstract

We introduce a memory-augmented extension of the Real-Time Fractional Tracking (R-TFT) algorithm, enabling real-time resonance classification across multiple interacting frequency vectors. This method combines the core multi-vector R-TFT projection approach with a structured Resonance Memory Engine (RME) that embeds past resonance states into a searchable, multi-dimensional space. The resulting system allows historical coherence tracking, cross-domain similarity detection, and generalization across dimensional contexts.

1 Background: Real-Time Fractional Tracking (R-TFT)

R-TFT is a method for identifying real-time resonance by projecting the angular velocity vector $\dot{\boldsymbol{S}}(t)$ of a dynamical system onto a normalized resonance vector $\boldsymbol{P}/\|\boldsymbol{P}\|$. This projection defines a scalar metric $R(t)$ that tracks how closely a system adheres to a phase-locked state. It provides instantaneous classification of orbital, neural, or quantum behavior into transient, resonant (librating), or chaotic modes.

2 Multi-Vector Extension

Standard R-TFT evaluates resonance against a single vector $\boldsymbol{P}$. However, many natural systems exhibit overlapping resonance modes. We extend R-TFT to accept a set of tracking vectors $\{\boldsymbol{P}_1, \boldsymbol{P}_2, \ldots, \boldsymbol{P}_n\}$, projecting $\dot{\boldsymbol{S}}(t)$ independently onto each:

$$R_i(t) = \frac{\dot{\boldsymbol{S}}(t) \cdot \boldsymbol{P}_i}{\|\boldsymbol{P}_i\|}$$

Each projection is background-corrected using an adaptive update:

$$R_{\text{clean},i}(t) = 2R_{\text{inner},i} - R_{\text{outer},i}$$

This allows the system to simultaneously track and isolate multiple competing or cooperative resonances in high-dimensional space.

Note: Here, "dimensionality" refers to the number of tracked resonance vectors, not spatial or geometric dimensions.

3 Resonance Memory Engine (RME)

To capture recurring or meaningful resonance states across runs, we introduce a lightweight memory structure that stores and retrieves multi-vector resonance projections. This Resonance Memory Engine (RME) indexes prior states based on:

- **Domain**: System context (e.g., orbital, neural, quantum)

- **Dimensionality**: Number of tracked vectors (1D, 2D, 3D, ...)
- **Resonance Set**: The set $\{\boldsymbol{P}_1, \ldots, \boldsymbol{P}_n\}$

Each stored record contains:

- Cleaned vector projection $\boldsymbol{R}_{\text{clean}}(t)$
- Original vectors $\boldsymbol{P}_i$
- Metadata (run ID, timestamp, tags)

4 Similarity Search and Pattern Recall

When a new system enters a resonance state, its real-time projections $\boldsymbol{R}_{\text{new}}(t)$ are compared against memory using cosine similarity:

$$\text{Similarity}_j = \frac{\boldsymbol{R}_{\text{new}} \cdot \boldsymbol{R}_{\text{stored}}^{(j)}}{\|\boldsymbol{R}_{\text{new}}\| \|\boldsymbol{R}_{\text{stored}}^{(j)}\|}$$

This provides fast identification of past coherence patterns, enabling the detection of recurrence, generalization across systems, or cross-domain analogues.

5 Demonstration

Using synthetic dynamical data, we demonstrate RME recall on a multi-vector setup:

- **Input**: $\boldsymbol{R}(t) = [0.11, 0.41, 0.88, 0.19]$, Vectors: $\boldsymbol{P}_1 = [3, -2], \boldsymbol{P}_2 = [5, 1]$
- **Match**: Domain: orbital, Dimensionality: 2D, Run ID: TRAPPIST_01
- **Score**: 0.99976 (near-perfect coherence match)

6 Conclusion

This standalone framework enables dimensional resonance memory using multi-vector projection in real time. The RME unlocks historical pattern tracking, resonance similarity search, and system-generalized inference across physical and abstract dynamical systems.