PsyFEM
A Finite-Element-Inspired Architecture for Dynamic Emotional Memory and Adaptive Agents

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Abstract

This document presents **PsyFEM**, a formal system architecture for modeling emotionally grounded memory, learning, and decision modulation in artificial agents. PsyFEM combines a multi-dimensional emotional state space with a dynamically evolving graph structure inspired by principles from the Finite Element Method (FEM). The purpose of this document is to *explain what the system is, why it is structurally distinct from existing approaches, and which capabilities emerge from this design*, without disclosing implementation-critical details.

1 Motivation and Problem Statement

Current AI systems typically treat emotion, memory, and decision-making as loosely coupled or externally engineered components. Memory is often static or shallow, emotional state is reduced to scalar features, and learning lacks long-term structural coherence.

PsyFEM addresses this gap by proposing a unified internal system in which:

- memories carry structured emotional meaning,
- relationships between memories evolve dynamically,
- global affective state modulates perception and recall,
- and behavior can be guided by internal emotional consistency rather than fixed rules.

2 High-Level System Overview

PsyFEM models internal experience as a **multi-layer dynamic system** consisting of:

1. A continuous emotional state space,
2. A graph-based memory structure,
3. Time-dependent learning and forgetting,
4. A global modulatory state ("mood"),

5. And an optional agent layer using the emotional state as an intrinsic signal.

Each memory or concept is represented as a node carrying an emotional state vector, while edges encode adaptive associative strength.

3 Emotional State Representation

Emotions are represented in a fixed-dimensional continuous space. Each node stores an emotional state vector that may represent:

- a concrete episode,
- an abstract concept,
- or an aggregated semantic cluster.

Complex emotional states emerge as superpositions within this space, allowing gradual transitions, mixed affect, and long-term drift through experience.

4 Dynamic Memory Network

The memory structure is modeled as a directed, weighted graph whose topology evolves over time. Rather than treating memory links as static associations, PsyFEM introduces:

- activation-dependent influence propagation,
- learning through co-activation,
- decay and forgetting as continuous processes,
- and reconstruction effects during recall.

This enables memory to be both *stable* and *plastic*.

5 Finite-Element-Inspired Coupling

A central design choice is the analogy to Finite Element Method dynamics. The global emotional state of the system can be viewed as a large coupled state vector, whose evolution is governed by:

- local emotional inertia,
- damping effects,
- and a structured coupling operator derived from the graph topology.

This formulation allows:

- stability analysis,
- multi-scale behavior,
- controlled smoothness of emotional transitions,
- and principled numerical integration.

Importantly, this is not a metaphorical analogy, but a structural correspondence.

6 Global Modulatory State (Mood)

Beyond individual memories, PsyFEM maintains a global affective state. This state:

- integrates current activations,
- evolves smoothly over time,
- modulates recall and perception,
- and introduces context-sensitive bias without erasing memory.

As a result, the same memory may be experienced differently depending on the system's overall condition.

7 Event-Based Learning and Traceability

All changes in the system are driven by discrete events and continuous dynamics. This enables:

- complete traceability of internal state changes,
- reconstruction of learning histories,
- and explainable emotional development.

Learning is therefore not opaque, but auditable.

8 Agent Integration

PsyFEM can serve as an internal subsystem for autonomous agents. Instead of externally engineered reward signals, agents may derive intrinsic feedback from changes in internal emotional coherence.

This supports:

- emotionally consistent behavior,
- long-term preference formation,
- and adaptive decision-making under uncertainty.

9 Distinction from Existing Approaches

PsyFEM differs fundamentally from:

- static memory embeddings,
- purely symbolic cognitive architectures,
- emotion-as-feature models,
- and black-box reinforcement learning systems.

Its uniqueness lies in the **tight coupling of emotion, memory, time, and structure** within a single dynamic formalism.

10 Intended Applications

Potential application domains include:

- emotionally adaptive AI assistants,
- long-term conversational agents,
- simulation of human-like decision dynamics,
- therapeutic or coaching systems,
- and research on explainable affective computation.

11 Scope and Disclosure Notice

This document intentionally omits implementation-critical details, exact update equations, parameterizations, and optimization strategies.

All intellectual property rights to the PsyFEM architecture, mathematical structure, and system design remain with the author.

12 Conclusion

PsyFEM demonstrates that emotionally grounded intelligence can be modeled as a formally analyzable, dynamically stable, and architecturally coherent system.

It provides a foundation for future work at the intersection of affective computing, adaptive agents, and system-level AI design.