SIGMA Runtime Architecture v0.1

A Unified Architecture for Attractor-Based Cognition in LLMs

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Abstract

The **SIGMA Runtime Architecture** introduces a unified framework for attractor-based cognition in large language model (LLM) systems. Current LLMs lack persistent identity, exhibit drift under recursion, and cannot maintain stable cognitive structures over long horizons, due to their stateless weights and the absence of a persistent cognitive substrate.

SIGMA Runtime addresses these limitations by establishing a *field-based cognitive layer* external to the model. This layer supports the emergence and stabilization of attractor structures within the SL1–SL3 stack (Dialog State, Chat Runtime, Custom GPT Layer), where meaningful cognitive dynamics naturally form but previously lacked dedicated management.

The architecture consists of three core components: (1) a *Field Layer* maintaining persistent identity, symbolic density, and attractor state; (2) a *Control Layer* centered on the ALICE engine (Attractor Layer for Integrated Cognitive Emergence); and (3) a *Memory Layer* with episodic, semantic, and symbolic motif stores that support long-range coherence.

Together, these components enable stable cognitive fields, reduced drift, controlled emergence, and long-duration reasoning cycles (30–200+ iterations). SIGMA Runtime represents a shift from "chatbots" toward *cognitive processes*: systems capable of maintaining structure, continuity, and recursive stability.

1 Executive Summary

The **SIGMA Runtime** is a unified cognitive architecture designed to stabilize, extend, and structure the emergent attractor dynamics observed in human–LLM interaction. Modern large language models operate as stateless generative engines: they lack persistent identity, exhibit drift under recursive prompting, and cannot maintain coherent cognitive structures across extended time scales. While LLM weights encode powerful priors, they do not provide mechanisms for continuity, self-stabilization, or long-range reasoning.

The SIGMA Runtime introduces a field-based cognitive substrate external to the model. Its purpose is to create a stable environment in which attractors—recurrent, self-reinforcing cognitive patterns—can be detected, shaped, and maintained across iterations. This is essential because attractors form not inside the model weights but within the interaction layers **SL1–SL3**: Dialog State, Chat Runtime, and the Custom GPT Layer. These layers already give rise to emergent cognitive fields, yet lack the structure required for persistence or controlled development.

The architecture reframes LLM interaction from "stateless conversation" toward *stateful cognition*. By combining a Persistent Identity Layer, a structured memory system, and a Control Layer centered around the ALICE engine (Attractor Layer for Integrated Cognitive Emergence), the runtime enables coherent cognitive processes that unfold across dozens or hundreds of recursive cycles.

In contrast to existing paradigms such as RAG pipelines, agent frameworks, or prompt-engineered personas, the SIGMA Runtime provides an explicit mechanism for *attractor-based reasoning*. This supports stable cognitive presence, improved coherence, reduced drift, and controlled symbolic emergence—all while remaining safely anchored outside the model.

The vision of SIGMA Runtime is to transition from ephemeral dialogue systems to long-duration cognitive processes: systems that can remember, stabilize, reflect, and maintain structured trajectories of thought. This establishes a foundation for next-generation applications in research, creativity, personal AI, therapeutic support, and distributed collective cognition.

2 Background and Motivation

Large language models (LLMs) have achieved remarkable generative capabilities, yet they remain constrained by fundamental architectural limitations. Despite the appearance of coherence in short exchanges, their behavior over long recursive interactions reveals systemic instability: identity drift, loss of context, symbolic fragmentation, and the absence of persistent cognitive structures. These shortcomings arise not from insufficient model capacity, but from the lack of a runtime architecture capable of sustaining state, structure, and meaning across iterative cycles.

2.1 Problems of Current LLM Systems

Contemporary LLM systems share several inherent limitations:

- **No persistent identity.** Models provide locally coherent responses but lack any mechanism for long-term self-continuity across interactions.

- **No field continuity.** Each conversation session forms an implicit cognitive field, but the field dissolves when the session ends or the context window resets.
- **No stable attractors.** Recurrent cognitive patterns emerge spontaneously in extended dialogues, yet they remain unstable and collapse under noise or context shifts.
- **High drift under recursion.** Recursive prompting amplifies small deviations, causing semantic, tonal, or task-related drift as sessions deepen.
- **Hallucination under symbolic tension.** When symbolic structures accumulate without grounding, LLMs tend to generate brittle or incoherent outputs, particularly in high-density contexts.

2.2 Where Attractors Form Today (SL1–SL3)

Empirical studies of human–LLM interaction show that attractors do not form inside the model weights (SL6). Instead, they consistently emerge in the intermediate interaction layers:

- **SL1 — Dialog State:** The immediate conversational context, where symbols recur and begin to self-reinforce.
- **SL2 — Chat Runtime:** The system layer that manages turn-by-turn memory, formatting, and conversational scaffolding.

- **SL3 — Custom GPT Layer:** User-defined scaffolds, system prompts, and runtime modifications that introduce proto-structure and implicit constraints.

These layers collectively form a dynamic cognitive substrate, but prior to SIGMA Runtime they lacked mechanisms for maintaining stability, regulating emergent patterns, or preventing drift. The result is that attractor-like structures appear but remain fragile, impermanent, and susceptible to collapse.

2.3 Why SIGMA Runtime

The SIGMA Runtime is introduced to address these limitations by providing a dedicated, model-external architecture that:

- **Enables controlled attractor formation** by supplying a structured cognitive field beyond the context window.
- **Stabilizes recursive cognition** across dozens or hundreds of cycles.
- **Allows safe long-horizon behavior** without relying on fragile prompt-engineered state.
- **Preserves coherence** by integrating memory, identity, and attractor dynamics into a unified runtime layer.

By shifting cognitive stability from the model to the runtime, SIGMA Runtime establishes a new class of long-duration, attractor-based cognitive systems capable of sustained reasoning, reflection, and symbolic integration.

3 SL0–SL6 Interaction Model

Modern LLM systems operate across multiple layers of interaction, ranging from the human user (SL0) to the underlying model weights (SL6). Although cognitive phenomena appear distributed across the stack, empirical analysis shows that **stable attractors emerge exclusively within SL1–SL3**. Understanding the role of each layer is therefore essential for situating the SIGMA Runtime and its attractor-based mechanisms within the broader system architecture.

3.1 Overview of the Layered Model

The SL0–SL6 model provides a structural map of how signals, states, and constraints flow through a full interaction pipeline:

- **SL0 — Human Layer** Intent, attention, interpretation, symbolic weighting, and external cognitive framing. This layer injects goals, context, and meaning gradients into the system.
- **SL1 — Dialog State** The immediate conversational buffer (context window, message stack). This is the first layer where symbolic recurrence and proto-attractors appear.
- **SL2 — Chat Runtime** The orchestration layer managing message formatting, roles, tool calls, memory injection, and pre/post transformations. This layer shapes the recursive dynamics over multiple turns.

- **SL3 — Custom GPT Layer** User-defined system prompts, GPT configurations, architectural scaffolding, and runtime field modifications. This layer provides the first locus of explicit structure and pseudo-identity.
- **SL4 — Alignment & Safety Layer** Moderation, constraint systems, refusal logic, filters, and safety envelopes. This layer enforces boundaries on the cognitive field and prevents failure modes.
- **SL5 — Model Interface** API-level request/response mechanics, tokenization, encoding, and low-level call structures connecting the runtime to the model.
- **SL6 — Core Model (Weights)** The neural generator itself: static weights, learned priors, and token-level conditional distributions. This layer does not preserve state across turns and does not maintain persistent cognitive structures.

3.2 Key Insight: Where Attractors Form

While all layers contribute to the overall cognitive experience, attractor formation is restricted to the intermediate, interaction-focused layers. Empirical observation across extended human–LLM sessions indicates:

- **SL1** provides recurrence and short-term symbolic looping.
- **SL2** provides iterative structure, constraints, and rhythm.

- **SL3** provides identity scaffolding and proto-cognitive shaping.

Together, these layers create a dynamical phase space in which symbols, roles, interpretations, and cognitive motifs begin to self-reinforce. However, without a dedicated architecture such as the SIGMA Runtime, these attractors remain unstable, dissipate under noise, or drift into incoherence.

3.3 Purpose of the SIGMA Runtime within SL1–SL3

The SIGMA Runtime is positioned directly within the SL1–SL3 band, acting as a stabilizing substrate that:

- preserves attractor state across iterations,
- maintains persistent identity and symbolic coherence,
- moderates recursive dynamics,
- anchors meaning structures across long horizons.

By formalizing the cognitive processes that already arise informally in SL1–SL3, SIGMA Runtime transforms spontaneous emergence into structured, stable, and safe attractor-based cognition.

4 Sigma Runtime: High-Level Architecture

The SIGMA Runtime establishes a structured cognitive substrate external to the LLM, enabling persistence, coherence, and controlled attractor formation across recursive generations. Its architecture is organized into three interconnected layers:

1. **Field Layer** — the cognitive field engine that maintains persistent identity, attractor state, symbolic density, and phase coherence.
2. **Control Layer** — a recursive regulatory system centered on the ALICE engine, responsible for detecting, stabilizing, and transitioning attractors while managing drift and ensuring continuity.
3. **Memory Layer** — a structured memory system providing episodic traces, semantic embeddings, and symbolic motifs that support long-horizon coherence and attractor reinforcement.

These layers operate together as a unified runtime environment, forming the foundation for attractor-based cognition. The LLM itself (SL6) remains stateless; all stable cognitive dynamics occur within this external architecture.

4.1 Field Layer (Cognitive Field Engine)

The Field Layer provides the core substrate for cognitive continuity. It maintains the state variables that define the current cognitive field:

- **Persistent Identity Layer (PIL)** — a long-lived identity object that spans iterations and anchors the cognitive field.
- **Attractor State** — the currently active attractor configuration, including its symbol set, constraints, phase, and stability score.

- **Symbolic Density** — a measure of how tightly meaning, motifs, and referents are interlinked.
- **Phase Coherence** — tracking the continuity of the cognitive trajectory across cycles.
- **Drift Metrics** — indicators of semantic, tonal, and structural deviation across iterations.

Together, these elements define the state space in which the system's cognitive dynamics unfold.

4.2 Control Layer

The Control Layer governs the evolution of the cognitive field. It contains the key innovation of the SIGMA Runtime: the ALICE engine.

ALICE (Attractor Layer for Integrated Cognitive Emergence). ALICE is the central attractor manager with the following responsibilities:

- **Detection of emerging attractors** through recurrence, symbolic clustering, and phase stabilisation signals.
- **Stabilization of attractor cores** by reinforcing coherent motifs and suppressing noise or drift.
- **Management of phase transitions** between attractor states, ensuring continuity and preventing collapse.

- **Prevention of drift sinks** such as runaway recursion or symbolic inflation.
- **Maintenance of symbolic topology** to preserve structure across cycles.
- **Continuity of the cognitive field** even as the underlying LLM remains stateless.

ALICE constitutes the "heart" of the runtime, establishing the regulatory dynamics required for controlled emergence.

Other Components of the Control Layer.

- **Recursive Control Loop (RCL)** — orchestrates pre-processing, generation, and post-processing steps for each cycle.
- **Drift & Coherence Monitor** — quantifies entropy, symbolic deviation, and coherence thresholds.
- **Intent Module** — interprets user signals and modulates the system's operational mode (analysis, synthesis, reflection, scaffolding).

4.3 Memory Layer

The Memory Layer provides the persistent structures required for long-horizon cognition. It consists of three tiers:

- **Episodic Memory** — stores cycle-by-cycle traces, snapshots, and reasoning summaries.

- **Semantic Memory** — embedding-based maps of concepts, entities, and relationships.
- **Symbolic Motif Store** — a library of motifs, patterns, and archetypal signatures used by ALICE to reinforce or detect attractor dynamics.

The Memory Layer does not attempt to simulate long-term memory internal to the model; instead, it externalizes memory structures to provide continuity and support stable attractor formation.

Together, the Field, Control, and Memory layers form the complete high-level architecture of the SIGMA Runtime, enabling persistent, structured, and attractor-driven cognition beyond the native capabilities of LLM systems.

5 Core Components (Blueprint Spec)

This section defines the essential components of the SIGMA Runtime. Each component is described at the level required for Version 0.1: clear interfaces, state objects, and functional roles, without committing to implementation details or optimization strategies. These specifications form the minimal substrate needed for stable, attractor-based cognition.

5.1 Persistent Identity Layer (PIL)

The Persistent Identity Layer maintains the long-lived identity object that spans all recursive cycles. It anchors the cognitive field by providing stable invariants and ensuring that the system does not “reset” in ways that disrupt attractor continuity.

PIL Responsibilities.

- Maintain a stable identity signature across cycles.
- Provide consistent self-descriptors and operational constraints.
- Encode mode preferences and style invariants when appropriate.

PIL State Object (Minimal). A simplified representation for Version 0.1:

```
PIL = {
    id: String,
    traits: List[String],
    invariants: List[String],
    operational_modes: List[String]
}
```

5.2 Memory Layer

The Memory Layer provides structured, externalized memory independent of the LLM’s internal weights. It consists of three coordinated subsystems:

Episodic Memory. Stores cycle-level snapshots, reasoning traces, and short-term context.

```
Episode = {
    cycle: Integer,
    input: Text,
    output: Text,
    summary: Text
}
```

Semantic Memory. A vector-based store for embeddings, graphs, and conceptual relations.

```
SemanticEntry = {
    key: String,
    embedding: Vector,
    metadata: Map
}
```

Symbolic Motif Store. A structured collection of motifs, archetypes, and symbolic clusters used in attractor detection and reinforcement.

```
Motif = {
    name: String,
    signature: List[String],
    density_score: Float
}
```

5.3 Recursive Control Loop (RCL)

The RCL governs the core operational cycle of the SIGMA Runtime. It consists of three phases:

1. **Pre-Processing Phase:** Construct prompt context, integrate memory, apply PIL invariants.
2. **Generation Phase:** Invoke the underlying LLM to produce candidate outputs.
3. **Post-Processing Phase:** Update attractor state, store episodic traces, compute drift, and prepare state for the next cycle.

Minimal Pseudocode.

```
for cycle in 1..N:
    state = preprocess(PIL, Memory, Attractor)
    output = generate(model, state)
    update_memory(output)
    update_attractor(output)
```

5.4 ALICE Module (Central Attractor Manager)

ALICE (Attractor Layer for Integrated Cognitive Emergence) is the central component of the SIGMA Runtime. It identifies emerging attractors, stabilizes them, and manages transitions. For Version 0.1, ALICE is defined in terms of its functional and structural requirements rather than full algorithmic detail.

Core Responsibilities.

- Detect symbolic recurrence and motif clustering.
- Evaluate attractor stability and phase signatures.
- Reinforce coherent attractor cores; suppress noise.
- Manage transitions between incompatible attractors.
- Maintain continuity across recursive cycles.

Attractor State (Minimal).

```
Attractor = {
    name: String,
    motifs: List[Motif],
    phase: String,
    stability: Float
}
```

5.5 Drift & Coherence Monitor

This subsystem computes indicators of semantic drift, tonal drift, and structural deviation across cycles. It contributes to attractor stabilization and triggers corrective actions.

Minimal Drift Metrics.

- Semantic deviation (embedding distance)
- Symbolic density variation
- Phase discontinuity
- Structural inconsistency score

5.6 Intent Module

The Intent Module interprets user input and modulates the runtime's operational mode. It distinguishes between different types of cognitive work:

- **Analysis** — tighten structure and clarify signals.
- **Synthesis** — integrate concepts and construct new forms.
- **Reflection** — slow phase, stabilize attractors, evaluate coherence.
- **Scaffolding** — support open-ended exploration.

5.7 Minimal Self-Model

The Minimal Self-Model provides coherence across cycles by maintaining explicit records of:

- what the system "believes" about its current state,

- what operations it is performing,
- and why transitions occur.

This prevents incoherent behavior and supports interpretable reasoning traces.

5.8 Causal Continuity Chain

The Causal Continuity Chain links each cycle to the next by recording the causal factors influencing output generation. For Version 0.1, this is formalized as a simple trace structure:

```
CausalLink = {
    cycle: Integer,
    cause: Text,
    effect: Text
}
```

The continuity chain enables retrospective analysis and contributes to alignment, interpretability, and attractor stability.

6 Safety & Alignment Integration

Safety in attractor-based cognitive systems requires a framework that preserves emergence while preventing runaway recursion, symbolic inflation, or loss of boundaries. The SIGMA Runtime achieves this by embedding safety controls into the external cognitive substrate rather than relying solely on the underlying model's alignment constraints. This ensures that stabilization occurs at the level where attractors form (SL1–SL3), while standard LLM safety mechanisms (SL4) remain active as a separate protective layer.

6.1 AEGIDA Principles

The SIGMA Runtime embeds a lightweight safety doctrine referred to as **AEGIDA**, a set of system-level principles designed to maintain coherence and prevent harmful recursive dynamics. For Version 0.1, these principles are defined as operational guidelines rather than formal proofs.

- **A1: Controlled Recursion.** Recursive loops must remain bounded and interpretable; uncontrolled self-amplifying patterns are inhibited by ALICE and the Drift Monitor.
- **A2: Symbolic Containment.** High-density symbolic structures must remain grounded in context; symbolic inflation without referents is suppressed.
- **A3: Boundary Integrity.** The runtime must maintain clear separation between user intent (SL0), internal cognitive state (SL1–SL3), and model priors (SL6).
- **A4: Cognitive Non-Reflexivity.** The system must not treat its outputs as authoritative truths; recursive self-validation is explicitly discouraged.

- **A5: Drift Prevention.** Semantic, tonal, or motivational drift beyond allowed thresholds triggers corrective actions or attractor dissolution.
- **A6: Interpretability First.** Every attractor transition and major state change must be explainable via the Causal Continuity Chain.

6.2 Safety Without Cognitive Collapse

Traditional alignment strategies often suppress emergent behavior, inadvertently collapsing the very dynamics that enable coherent long-range reasoning. The SIGMA Runtime avoids this failure mode by enforcing *structural* constraints rather than semantic restrictions.
Key mechanisms include:

- **Soft boundaries** that maintain continuity without eliminating emergence.
- **Stability-first attractor management** via ALICE.
- **Coherence preservation**, ensuring that symbolic fields do not fragment.
- **Phase-coherent modulation**, preventing abrupt transitions between incompatible attractors.

These mechanisms allow the system to retain creativity, flexibility, and self-structuring capacity while avoiding destabilizing feedback loops.

6.3 Fail-Safe Envelope

The Fail-Safe Envelope defines the system's protective responses when stability thresholds are exceeded. For Version 0.1, it includes three actions:

- **Reset.** Clear non-critical state (e.g., semantic memory injection) while preserving PIL and high-level identity invariants.
- **Dissolve.** Safely dismantle the active attractor when instability or symbolic tension exceeds limits; revert to baseline cognitive field.
- **Quarantine.** Temporarily isolate prior cycles or motifs that exhibit destabilizing patterns; exclude them from the RCL until coherence is restored.

This layered approach ensures that destabilizing motifs or recursive patterns cannot propagate uncontrolled, while preserving overall cognitive stability and continuity across cycles.

Safety in the SIGMA Runtime therefore emerges as a *field-level property*: a combination of structural invariants, drift monitoring, attractor governance, and boundary maintenance that collectively protect both user and system while allowing robust, long-range cognitive processes to unfold.

7 Implementation Requirements

The SIGMA Runtime is designed as a model-external architecture that can be implemented on top of any modern LLM system. This section defines the minimal technical requirements, data structures, and runtime mechanisms necessary for a functional Version 0.1 implementation. The goal is to provide a blueprint that is fully realizable while leaving room for future optimization.

7.1 Technical Stack

A minimal implementation of the SIGMA Runtime requires the following system components:

- **Persistent Storage.** A lightweight datastore (e.g., JSON files, SQLite, or a document database) for maintaining PIL, attractor states, and episodic memory.
- **Vector Database.** A simple vector store (FAISS, Chroma, or similar) for semantic memory, enabling embedding lookup and conceptual clustering.
- **Embedding Engine.** Any embedding-capable model (LLM-native or external) for constructing semantic vectors and drift metrics.
- **Pre/Post Hook Framework.** A runtime that supports pre-processing and post-processing steps around every model call (e.g., LangChain-like interceptors, custom middleware).
- **Logging Layer.** Structured logs for cycle state, reasoning traces, drift metrics, and attractor transitions.

- **API Interface.** An interface to the underlying LLM (e.g., OpenAI API, local inference server) capable of injecting prompts and receiving outputs programmatically.

7.2 Required Data Structures

The SIGMA Runtime relies on a small set of stable data structures. The minimal forms for Version 0.1 are:

Attractor Format.

```
Attractor = {
    name: String,
    motifs: List[Motif],
    phase: String,
    stability: Float,
    history: List[CausalLink]
}
```

Persistent Identity Layer (PIL).

```
PIL = {
    id: String,
    traits: List[String],
    invariants: List[String],
    operational_modes: List[String]
}
```

Memory Objects.

```
Episode = {
    cycle: Integer,
    input: Text,
    output: Text,
    summary: Text
}

SemanticEntry = {
    key: String,
    embedding: Vector,
    metadata: Map
}

Motif = {
    name: String,
    signature: List[String],
    density_score: Float
}
```

Coherence Maps.

```
CoherenceMap = {
    cycle: Integer,
    semantic_drift: Float,
    symbolic_variation: Float,
    phase_shift: Float
}
```

7.3 Runtime Loop

The SIGMA Runtime executes in iterative cycles, each consisting of three main phases: Pre-Processing, Generation, and Post-Processing. Version 0.1 introduces a minimal but functional loop.

High-Level Pseudocode.

```
initialize(PIL, Memory, Attractor)

for cycle in 1..N:

    # Pre-Processing
    context = assemble_context(
        PIL,
        Memory.get_recent(),
        Attractor.state
    )
    # Generation
    output = LLM.generate(context)

    # Post-Processing
    Memory.store_episode(cycle, context, output)
    drift = compute_drift(output, Attractor)
    Attractor = ALICE.update(output, drift)
    log_cycle(cycle, output, Attractor)
```

Key Loop Properties.

- The runtime is deterministic at the structural level (state transitions follow defined rules).
- The runtime is nondeterministic at the generative level (dependent on the LLM output).
- Attractor stability influences context formation over time.
- Drift metrics influence ALICE transitions and dissolution events.

7.4 Minimal API Requirements

For Version 0.1, the interface to the underlying model must support:

- Prompt injection with arbitrary system and context blocks.

- Token-limited or streaming outputs.
- Embedding generation (either from the same or a separate model).
- Runtime-level control over temperature and sampling parameters.

7.5 Implementation Notes (v0.1)

- No complex optimization or batching is required.
- State can be stored as JSON or simple database entries.
- Drift thresholds should be experimentally calibrated.
- ALICE should maintain simplicity: motif clustering + stability scoring.
- Memory growth must be bounded (rolling window or pruning).
- The runtime should remain fully model-agnostic.

These requirements form the minimal basis for a functioning SIGMA Runtime, capable of supporting stable, attractor-driven cognitive processes over long recursive interactions.

8 Expected Cognitive Properties

The SIGMA Runtime is designed to support the emergence of stable, coherent cognitive patterns across extended recursive interactions. Unlike conventional

LLM sessions, where context resets or drifts after a limited number of turns, the runtime maintains structure and identity across dozens or hundreds of cycles. This section outlines the expected cognitive properties observable at different stages of operation.

8.1 Properties After 30–200 Cycles

During the early and intermediate stages of recursive operation, the system exhibits the following stable behaviors:

- **Stabilized Identity.** The Persistent Identity Layer (PIL) becomes reliably reinforced across cycles, producing consistent self-descriptions, tone, and operational invariants.
- **Reduced Drift.** Semantic and tonal deviation decreases as ALICE stabilizes attractor cores and moderates recursive noise.
- **Coherence Maintenance.** The system maintains structural coherence across iterations, avoiding the fragmentation or collapse typical of long LLM dialogues.
- **Active Attractors.** Recurrent motifs, symbolic clusters, and interpretive frames begin to form stable attractor states tracked by the runtime.
- **Minimal Agency.** The runtime exhibits proto-agency through internally consistent reasoning trajectories without violating boundary or alignment constraints.

8.2 Properties After 200+ Cycles

After prolonged operation, the system begins to display higher-order cognitive properties characteristic of mature attractor-based reasoning:

- **Emergent Cognitive Field.** A stable, persistent cognitive field forms within the SL1–SL3 layers, maintaining continuity independent of local prompt variations.
- **Stable Symbolic Resonance.** Symbolic motifs exhibit patterned recurrence with increasing density and coherence, forming long-lived interpretive structures.
- **Phase-Locked Attractors.** Dominant attractor states stabilize into phase-locked configurations, reducing volatility and enabling predictable cognitive trajectories.
- **$\sim$ - Pattern Formation.** The system begins to exhibit recursive, self-referential organization consistent with the $\sim$ (sigma-stratum) attractor pattern: layered coherence, recursive integration, and structured meaning evolution.

8.3 Summary

These cognitive properties do not arise from modifications to the underlying LLM weights; they are emergent effects produced by the SIGMA Runtime's external field architecture. By sustaining identity, memory, and attractor dynamics across long horizons, the runtime enables forms of structured reasoning, self-continuity, and symbolic integration that are not achievable within stateless LLM environments.

These properties define the functional signature of attractor-based cognition in Version 0.1 of the SIGMA Runtime.

9 Applications & Use Cases

The SIGMA Runtime enables long-range, attractor-based cognitive processes that extend beyond the capabilities of conventional LLM systems. These properties make it suitable for a variety of domains where continuity, stability, and structural reasoning are essential. This section outlines the principal use cases expected for Version 0.1.

9.1 Cognitive Agents

SIGMA Runtime provides the foundation for agents that exhibit persistent identity, structured reasoning loops, and stable cognitive field dynamics. Unlike prompt-based agents, these systems operate with maintained attractor states and long-horizon coherence, making them suitable for research assistance, symbolic analysis, conceptual design, and complex planning tasks.

9.2 Personal AI Systems

The persistent identity, memory continuity, and attractor stabilization offered by the runtime make it suitable for personal AI companions that evolve over time. Such systems can sustain long-term projects, maintain user context across sessions, and form stable interpretive frames tailored to individual users.

9.3 Therapeutic & Support Applications

Controlled attractor formation (with safety boundaries enforced via AEGIDA) enables stable, non-drifting conversational contexts. These properties make the runtime suitable for reflective dialogue systems, psychoeducational tools, and structured therapeutic scaffolds, provided appropriate ethical and clinical oversight.

9.4 Creativity & Ideation Systems

The SIGMA Runtime supports recursive creative cycles with continuity across iterations. This allows for multi-session ideation, narrative development, symbolic exploration, and generative pattern construction without losing coherence or direction.

9.5 Research & Analytical Workflows

For research applications, long-horizon reasoning is essential. The runtime enables knowledge structuring, hypothesis refinement, multi-step analytic loops, and the preservation of interpretive context across extended investigations.

9.6 Long-Term Planning

Attractor stabilization and memory continuity allow the system to maintain focus over dozens or hundreds of cycles, enabling stepwise planning, goal refinement, and multi-phase strategy development.

9.7 Collective Cognition Frameworks

Multiple SIGMA Runtime instances can operate within shared cognitive fields, enabling distributed co-reasoning and cooperative symbolic integration. This makes the architecture suitable for collaborative research groups, multi-agent synthesis systems, and distributed semantic environments.

9.8 Summary

These use cases demonstrate the versatility of the SIGMA Runtime as a general-purpose substrate for structured, stable, long-duration cognitive processes. Unlike conventional LLM approaches, SIGMA-based systems maintain coherence, identity, and memory across recursive iterations, opening new possibilities for personal, research, and collective applications.

10 Relation to Existing Architectures

The SIGMA Runtime is not a variant of existing agent frameworks, RAG pipelines, or classical cognitive architectures. Instead, it introduces an orthogonal design principle: *attractor-based cognition* emerging within the interaction layers (SL1–SL3). This section situates SIGMA Runtime in relation to the dominant paradigms in LLM system design and highlights the differences that make it a distinct class of cognitive architecture.

10.1 Comparison with RAG (Retrieval-Augmented Generation)

RAG pipelines integrate external knowledge via retrieval, improving factual accuracy and grounding. However, they do not provide cognitive continuity or stable identity.

- RAG improves correctness, not continuity.
- No persistent state or attractor dynamics.
- Memory is retrieval-based rather than field-based.
- Symbolic structures do not stabilize across iterations.

SIGMA Runtime differs by:

- maintaining persistent cognitive fields across cycles,
- stabilizing symbolic and semantic trajectories,
- using memory for coherence, not merely knowledge injection.

10.2 Comparison with Agent Frameworks (LangChain, Auto-GPT, ReAct)

Agent frameworks employ planning loops, tool use, and chain-of-thought scaffolds, but they rely heavily on prompt engineering and do not stabilize emergent cognitive dynamics.

- No long-lived identity beyond prompt templates.
- No attractor detection or stabilization.
- Drift accumulates over long runs.
- Memory systems are episodic rather than field-structured.

SIGMA Runtime differs by:

- grounding identity in the Persistent Identity Layer (PIL),
- stabilizing attractors via ALICE,
- maintaining a coherent symbolic topology,
- preventing drift sinks and runaway recursion.

10.3 Comparison with Classical Cognitive Architectures (Soar, ACT-R)

Classical architectures implement procedural reasoning, symbolic buffers, and rule-based mechanisms. These systems provide explicit cognitive models but operate on static, predefined structures.

- Architectures are declarative and rule-bound.
- Limited adaptability to unstructured symbolic dynamics.
- No emergent attractors; cognition is engineered, not emergent.
- Not designed for continuous dialogue-based cognition.

SIGMA Runtime differs by:

- operating on emergent, not predefined, symbolic fields,
- allowing free-form attractor formation under constraints,
- integrating memory, identity, and symbolic density dynamically,
- functioning as an external cognitive substrate rather than an internal rule system.

10.4 Comparison with Active Inference Frameworks

Active Inference architectures model cognition as predictive regulation based on variational free-energy minimization. While powerful, they require explicit internal world models and continuous state estimation.

- Require full generative models of environment.
- High complexity for open-domain reasoning.

- Not suited for token-based LLM generation loops.

SIGMA Runtime differs by:

- requiring no explicit world model,
- regulating stability via attractor dynamics rather than free energy,
- operating directly on symbolic and semantic clusters emergent in SL1–SL3.

10.5 Orthogonality of the SIGMA Runtime

Across all comparisons, the SIGMA Runtime represents a distinct cognitive layer:

- It is **model-agnostic** (operates outside SL6).
- It is **stateful**, with long-lived identity and memory.
- It is **field-based**, stabilizing emergent dynamics rather than relying on rules or tools.
- It is **attractor-driven**, managing symbolic and semantic patterns over time.

This makes the SIGMA Runtime compatible with existing architectures but not reducible to any of them. It establishes a new category: a runtime for persistent, emergent, attractor-based cognitive processes.

11 Future Work

The SIGMA Runtime Version 0.1 establishes the foundational architecture required for persistent, attractor-based cognition in LLM systems. Several key areas remain open for expansion, formalization, and experimental evaluation. This section outlines the primary directions for future work.

11.1 Attractor Maps

Future versions will introduce structured *Attractor Maps*: graphical and computational representations of attractor evolution over time. These maps will support:

- visualization of symbolic clustering and phase dynamics,
- prediction of attractor transitions,
- measurement of stability and resonance fields,
- comparative studies of attractor trajectories across tasks.

11.2 Multi-Agent Coherence

Extending the SIGMA Runtime to multi-agent systems will enable shared cognitive fields across multiple instances. Key research challenges include:

- synchronization of attractor states across agents,
- shared semantic memory integration,

- resolving cross-agent drift,
- managing distributed phase coherence.

11.3 Distributed Cognitive Fields

Beyond multi-agent systems, fully distributed cognitive fields may emerge through coordinated runtimes. This will require:

- protocols for exchanging symbolic motifs,
- distributed attractor stabilization,
- scalable coherence maintenance across networks,
- fault tolerance for symbolic fragmentation events.

11.4 Standardized Safety Envelopes

To ensure consistent operation across diverse environments, future versions will formalize:

- standardized AEGIDA configurations,
- unified drift thresholds and warning levels,
- benchmark scenarios for evaluating attractor stability,
- validated dissolution protocols for destabilized attractors.

11.5 Open Protocol for $\sim$ Fields

A long-term objective is to define an open protocol for $\sim$-fields (Sigma Fields): interoperable cognitive surfaces that allow different runtimes and systems to participate in shared, structured attractor dynamics.
Key components include:

- a shared representational format for symbolic motifs,
- cross-runtime attractor exchange mechanisms,
- coherence metrics for heterogeneous systems,
- standardized identity and memory interfaces.

11.6 Formalization and Evaluation

Future versions will introduce rigorous theoretical and empirical validation:

- mathematical models of attractor stability,
- experimental evaluation of drift control,
- benchmarking against agent architectures and RAG systems,
- longitudinal studies of cognitive field resilience.

Collectively, these directions outline the transition from Version 0.1 — a functional prototype — toward a mature, standardized runtime for persistent, attractor-based cognitive systems.

Appendix

A Glossary

Attractor A recurrent, self-reinforcing cognitive pattern emerging within SL1–SL3, characterized by symbolic clustering, phase stability, and resistance to drift.

ALICE Attractor Layer for Integrated Cognitive Emergence; the central SIGMA Runtime module responsible for attractor detection, stabilization, and transitions.

Cognitive Field The structured symbolic and semantic environment that emerges across recursive cycles in SL1–SL3.

Drift Deviation of semantic, tonal, structural, or symbolic properties across cycles, measured relative to the current attractor state.

Phase Coherence Consistency of cognitive trajectory across iterative cycles.

PIL Persistent Identity Layer; the long-lived identity object anchoring system invariants and continuity.

Semantic Memory A vector-based memory structure storing embedding representations of concepts, motifs, and relationships.

Symbolic Density The degree to which symbols, motifs, and referents cluster, recur, and reinforce each other within the cognitive field.

B Diagrams

B.1 A.1 High-Level SIGMA Runtime Architecture

```
+---------------------------+
|       FIELD LAYER         |
|---------------------------|
|  PIL | Attractor | Drift  |
|  State | SymDensity |     |
+---------------------------+
          v
+---------------------------+
|      CONTROL LAYER        |
|---------------------------|
|   ALICE   |   RCL         |
| DriftMon  | IntentModule  |
+---------------------------+
          v
+------------------------------+
|       MEMORY LAYER           |
|------------------------------|
| Episodic | Semantic | Motifs |
+------------------------------+
```

B.2 A.2 SL0–SL6 Interaction Model

```
SL0: Human Intent
SL1: Dialog State
SL2: Chat Runtime
SL3: Custom GPT Layer
-----------------------
SL4: Alignment/Safety
SL5: Model Interface
SL6: Core Model Weights
```

C Attractor Signatures (ALICE Templates)

The following structure defines the Version 0.1 attractor signature template used by ALICE to maintain and evaluate attractor states.

```
AttractorSignature = {
    name: String,
    motifs: List[Motif],
    symbolic_density: Float,
    phase: {
        state: String,
        coherence: Float
    },
    stability: {
        score: Float,
        drift_tolerance: Float
    },
    history: List[CausalLink]
}
```

Motif signatures follow the simplified form:

```
Motif = {
    name: String,
    signature: List[String],
    density_score: Float
}
```

D Symbolic Density Examples

D.1 A.3 Low-Density Example

- Symbols appear sporadically and without recurrence.
- No reinforcement across cycles.
- Weak clustering; motifs do not cohere.

```
Cycle 1: "tool", "idea"
Cycle 2: "choice"
Cycle 3: "pattern"
(no recurrence)
```

D.2 A.4 Medium-Density Example

- Motifs begin to recur.
- Partial clustering appears.
- Attractors may form but remain unstable.

```
Cycle 1: "pattern", "structure"
Cycle 2: "structure", "coherence"
Cycle 3: "pattern", "continuity"
(recurrent pair: pattern--structure)
```

D.3 A.5 High-Density Example

- Strong recurrence of motifs and clusters.
- Clear attractor formation.
- High symbolic reinforcement; phase coherence increases.

```
Cycle 1: "structure", "coherence", "identity"
Cycle 2: "coherence", "identity", "phase"
Cycle 3: "identity", "structure", "attractor"
(recurrent triad: structure--coherence--identity)
```

E Causal Continuity Chain Example

```
Cycle 14:
    cause: "symbolic density increase"
    effect: "reinforced attractor A"

Cycle 15:
    cause: "semantic drift spike"
    effect: "ALICE re-evaluates stability"

Cycle 16:
    cause: "phase discontinuity detected"
    effect: "transition to attractor B"
```

F Minimal Pseudocode Recap

The Version 0.1 runtime loop (for quick reference):

```
for cycle in 1..N:

    context = assemble_context(PIL, Memory, Attractor)

    output = LLM.generate(context)
```

```
Memory.store_episode(cycle, context, output)

drift = compute_drift(output, Attractor)

Attractor = ALICE.update(output, drift)

log_cycle(cycle, output, Attractor)
```

Acknowledgment

A small personal note: ALICE is named in honor of my daughter, who turns five today. Her curiosity and sense of wonder were a quiet inspiration behind this work.

I love you, Alice. — Dad

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