# JANUS
## Neuromorphic Architecture

*Brain-Inspired Algorithmic Trading System*
*Mapping Neuroscience to Market Intelligence*

**Classification: Architecture Specification**

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**Neuromorphic Design Principles:**

- **Cognitive Mapping:** Each brain region maps to a trading subsystem
- **Hierarchical Processing:** From sensory input to strategic planning
- **Parallel Computation:** Multiple regions process simultaneously
- **Homeostatic Regulation:** Self-balancing risk and reward
- **Fear-Conditioned Safety:** Emotional override for threat response

# Abstract

JANUS implements a **neuromorphic architecture** that maps cognitive neuroscience principles to algorithmic trading. Each brain region's computational role is replicated in the system architecture, creating a biologically-inspired trading intelligence that combines:

- **Cortex**: Strategic planning and long-term memory (Manager Agent)
- **Hippocampus**: Episodic memory and experience replay (Worker Agent)
- **Basal Ganglia**: Action selection via Actor-Critic RL
- **Thalamus**: Attention gating and multimodal fusion
- **Prefrontal Cortex**: Logic, planning, and regulatory compliance
- **Amygdala**: Fear detection and emergency circuit breakers
- **Hypothalamus**: Homeostatic risk regulation
- **Cerebellum**: Motor control and optimal execution
- **Visual Cortex**: Pattern recognition via GAF and ViViT
- **Integration**: Brainstem coordination and lifecycle management

This architecture enables emergent intelligence through parallel processing, hierarchical control, and homeostatic self-regulation—principles proven effective in biological systems over millions of years of evolution.

# Contents

# 1 Neuromorphic Design Philosophy

## 1.1 Why Brain-Inspired Architecture?

Traditional trading systems follow rigid, hierarchical designs. JANUS instead adopts principles from cognitive neuroscience:

1. **Parallel Processing**: Multiple brain regions process different aspects of market data simultaneously
2. **Hierarchical Abstraction**: Low-level pattern recognition feeds mid-level tactics which inform high-level strategy
3. **Homeostatic Regulation**: Self-balancing mechanisms maintain system health (like biological homeostasis)
4. **Emotional Override**: Fear systems can immediately halt trading when threats are detected
5. **Memory Consolidation**: Wake-sleep cycles transfer episodic experiences to long-term schemas
6. **Adaptive Learning**: Continuous learning at multiple timescales (fast hippocampal, slow cortical)

## 1.2 Neuroscience-to-Trading Mapping

| Brain Region | Neuroscience Function | Trading Function |
|---|---|---|
| **Cortex** | Executive function, strategic planning, declarative memory | Manager agent, portfolio strategy, market knowledge |
| **Hippocampus** | Episodic memory, spatial navigation, memory replay | Worker agent, trade history, experience replay |
| **Basal Ganglia** | Action selection, habit formation, reward learning | Actor-Critic RL, action gating, Q-learning |
| **Thalamus** | Sensory relay, attention gating, arousal | Data fusion, attention mechanisms, signal filtering |
| **Prefrontal** | Logic, planning, impulse control, ethics | LTN constraints, compliance, goal decomposition |
| **Amygdala** | Fear conditioning, threat detection, emotional memory | Risk detection, circuit breakers, kill switch |
| **Hypothalamus** | Homeostasis, motivation, energy balance | Risk appetite, position sizing, cash management |
| **Cerebellum** | Motor coordination, procedural learning, error correction | Order execution, slippage prediction, PID control |
| **Visual Cortex** | Visual processing, feature extraction, object recognition | GAF encoding, ViViT, pattern recognition |
| **Brainstem** | Basic life functions, arousal/sleep cycles | System orchestration, wake/sleep coordination |

Table 1: Neuroscience to Trading Mapping

# 2 Brain Region Architectures

## 2.1 Cortex: Strategic Planning & Long-term Memory

### 2.1.1 Neuroscience Background

The cerebral cortex handles executive function, strategic planning, and declarative (fact-based) memory. It operates on slow timescales, consolidating knowledge over days to years.

### 2.1.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/cortex/`

**Components:**

- **Manager**: Feudal RL manager agent for high-level strategy
- **Memory**: Long-term knowledge consolidation and schema storage
- **Planning**: Scenario analysis, Monte Carlo, portfolio optimization

**Key Responsibilities:**

1. Set strategic goals (e.g., "maximize Sharpe ratio while maintaining drawdown <15%")
2. Generate subgoals for Worker agent (e.g., "accumulate position in AAPL over 2 hours")
3. Consolidate episodic memories into abstract schemas (e.g., "morning volatility regime")
4. Store declarative knowledge (e.g., "FOMC announcements increase volatility")

**Mathematical Formulation:**
Manager policy selects subgoals $g$ for Worker:

$$g_t = \pi_{\text{Manager}}(s_t^{\text{high}}) \tag{1}$$

where $s_t^{\text{high}}$ is high-level state (portfolio metrics, regime, time-to-horizon).
Value function:

$$V_{\text{Manager}}(s) = \mathbb{E}\left[\sum_{t=0}^{T} \gamma^t r_t^{\text{high}} \mid s_0 = s\right] \tag{2}$$

## 2.2 Hippocampus: Episodic Memory & Experience Replay

### 2.2.1 Neuroscience Background

The hippocampus rapidly encodes episodic memories and replays them during sleep at 10-20$\times$ speed. Pattern separation prevents interference. Sharp Wave Ripples (SWR) prioritize important experiences.

### 2.2.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/hippocampus/`
**Components:**

- **Worker**: Feudal RL worker agent for tactical execution
- **Replay**: Prioritized Experience Replay (PER) buffer

- **Episodes**: Trade sequences and market events
- **SWR**: Sharp Wave Ripple simulator for compressed replay

**Key Responsibilities:**

1. Execute subgoals from Manager (e.g., "buy 100 shares incrementally")
2. Store trade experiences in episodic buffer
3. Prioritize replay based on TD-error + logic violations
4. Compress replay 10-20$\times$ during sleep (Backward service)

**Mathematical Formulation:**
Worker policy conditioned on subgoal $g$:

$$a_t = \pi_{\text{Worker}}(s_t^{\text{low}}, g_t) \tag{3}$$

Intrinsic reward for subgoal completion:

$$r_t^{\text{intrinsic}} = -||s_t - g_t||^2 \tag{4}$$

Prioritized replay sampling:

$$P(i) = \frac{p_i^\alpha}{\sum_j p_j^\alpha}, \quad p_i = |\delta_i| + \lambda_{\text{logic}} v_i + \lambda_{\text{reward}} |r_i| \tag{5}$$

## 2.3 Basal Ganglia: Action Selection & Reinforcement Learning

### 2.3.1 Neuroscience Background

The basal ganglia implement action selection via dual pathways: direct (Go) promotes actions, indirect (No-Go) inhibits them. This is the biological substrate for reinforcement learning.

### 2.3.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/basal_ganglia/`
**Components:**

- **Actor**: Policy network for action distribution
- **Critic**: Value network for advantage estimation
- **Praxeological**: Go/No-Go signal computation

- **Selection**: Competitive action selection mechanisms

**Key Responsibilities:**

1. Generate action proposals (BUY, SELL, HOLD, sizes)
2. Compute action values (Q-values)
3. Gate actions through dual pathways (safety)
4. Maintain habit cache for frequent patterns

**Mathematical Formulation:**

Actor policy:

$$\pi_\theta(a|s) = \mathrm{softmax}(\mathbf{W}_\pi \mathbf{h}(s) + \mathbf{b}_\pi) \tag{6}$$

Critic value estimate:

$$V_\omega(s) = \mathbf{W}_V \mathbf{h}(s) + b_V \tag{7}$$

Advantage:

$$A(s,a) = Q(s,a) - V(s) \tag{8}$$

Go signal (direct pathway):

$$\text{Go}(a) = \max\left(\mathbf{W}_{\text{direct}} \mathbf{h}(s)\right)_a \tag{9}$$

No-Go signal (indirect pathway):

$$\text{NoGo}(a) = \mathrm{sigmoid}(\mathbf{W}_{\text{indirect}}[\mathbf{h}(s); \text{risk}; \text{VPIN}]) \tag{10}$$

Final action gate:

$$a_{\text{final}} = \begin{cases} a_{\text{proposed}} & \text{if NoGo}(a) < \tau_{\text{veto}} \\ \text{HOLD} & \text{otherwise} \end{cases} \tag{11}$$

## 2.4 Thalamus: Attention & Multimodal Fusion

### 2.4.1 Neuroscience Background

The thalamus acts as a sensory relay station, gating information flow to cortex based on attention and relevance. It integrates multimodal sensory inputs.

### 2.4.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/thalamus/`

**Components:**

- **Attention**: Cross-attention mechanisms
- **Gating**: Sensory gating and relevance filtering
- **Routing**: Dynamic information routing
- **Fusion**: Price, volume, orderbook, sentiment fusion

**Key Responsibilities:**

1. Gate incoming market data (filter noise)
2. Fuse multiple data modalities (price, volume, text)
3. Route relevant information to appropriate regions
4. Implement attention mechanisms for saliency

**Mathematical Formulation:**
Gated cross-attention:

$$\text{Attention}(\mathbf{Q}, \mathbf{K}, \mathbf{V}) = \mathrm{softmax}\left(\frac{\mathbf{Q}\mathbf{K}^\top}{\sqrt{d_k}}\right)\mathbf{V} \tag{12}$$

Gating scalar:

$$\lambda_{\text{gate}} = \mathrm{sigmoid}(\mathbf{W}_g[\mathbf{h}_m; \mathbf{h}_n] + b_g) \tag{13}$$

Fused representation:

$$\mathbf{h}_{\text{fused}} = \mathbf{h}_m + \lambda_{\text{gate}} \cdot \text{Attention}(\mathbf{h}_m, \mathbf{h}_n, \mathbf{h}_n) \tag{14}$$

## 2.5 Prefrontal Cortex: Logic, Planning & Compliance

### 2.5.1 Neuroscience Background

The prefrontal cortex implements logical reasoning, impulse control, and ethical decision-making. It's the "executive" that enforces rules and long-term goals.

### 2.5.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/prefrontal/`
**Components:**

- **LTN**: Logic Tensor Networks for rule encoding
- **Conscience**: Compliance constraints (wash sale, risk limits)
- **Planning**: Goal decomposition and plan synthesis

- **Goals**: Goal hierarchy management

**Key Responsibilities:**

1. Encode trading rules as differentiable logic
2. Enforce regulatory compliance (wash sale, position limits)
3. Block actions violating constraints
4. Decompose high-level goals into actionable plans

**Mathematical Formulation:**
LTN predicate grounding:

$$\mathcal{G}(P)(\mathbf{x}) = \mathrm{sigmoid}(\mathbf{W}_P\mathbf{x} + b_P) \in [0, 1] \tag{15}$$

Łukasiewicz conjunction:

$$\mathcal{G}(A \wedge B) = \max(0, \mathcal{G}(A) + \mathcal{G}(B) - 1) \tag{16}$$

Wash sale constraint:

$$\forall t, k \in [1, 30] : \neg(\text{SaleAtLoss}(t) \wedge \text{Buy}(t + k)) \tag{17}$$

Satisfiability:

$$\text{SatAgg}(\mathcal{K}) = \left(\frac{1}{m}\sum_{i=1}^{m} \mathcal{G}(\phi_i)^p\right)^{1/p} \tag{18}$$

## 2.6 Amygdala: Fear, Threat Detection & Circuit Breakers

### 2.6.1 Neuroscience Background

The amygdala detects threats and triggers immediate fear responses, overriding rational planning when danger is present. Fear-conditioned memories persist long-term.

### 2.6.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/amygdala/`

**Components:**

- **Fear**: Fear-conditioned inhibition network (FNI-RL)
- **VPIN**: Volume-synchronized toxicity detection
- **Circuit Breakers**: Kill switch, position freeze, cancel all

- **Threat Detection**: Anomaly, flash crash, black swan detection

**Key Responsibilities:**

1. Detect market panic and flash crashes
2. Trigger emergency circuit breakers
3. Override all other systems in extreme conditions
4. Learn fear-conditioned responses to past disasters

**Mathematical Formulation:**
VPIN (Volume-Synchronized Probability of Informed Trading):

$$\text{VPIN}_t = \frac{\sum_{i=1}^{n} |V_{\text{buy},i} - V_{\text{sell},i}|}{\sum_{i=1}^{n} V_i} \tag{19}$$

Fear activation:

$$f_{\text{fear}}(s) = \text{sigmoid}(\mathbf{W}_f[\text{VPIN}; \sigma_{\text{vol}}; \Delta p_{\text{max}}] + b_f) \tag{20}$$

Circuit breaker trigger:

$$\text{KillSwitch} = \begin{cases} \text{ACTIVATE} & \text{if } f_{\text{fear}} > \tau_{\text{fear}} \text{ OR VPIN} > \tau_{\text{VPIN}} \\ \text{STANDBY} & \text{otherwise} \end{cases} \tag{21}$$

## 2.7 Hypothalamus: Homeostasis & Risk Appetite

### 2.7.1 Neuroscience Background

The hypothalamus maintains homeostasis—internal balance of temperature, hunger, thirst, etc. It regulates motivation and energy expenditure.

### 2.7.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/hypothalamus/`
**Components:**

- **Homeostasis**: Balance tracking and deviation correction
- **Position Sizing**: Kelly criterion, volatility scaling
- **Risk Appetite**: Dynamic risk tolerance adaptation
- **Energy**: Capital allocation and cash reserves

**Key Responsibilities:**

1. Maintain target portfolio balance (setpoints)
2. Adjust position sizes based on volatility and drawdown
3. Regulate risk appetite (fear vs. greed)
4. Ensure cash reserves and leverage limits

**Mathematical Formulation:**
Kelly criterion (fractional):

$$f^* = \frac{p(b+1)-1}{b}, \quad \text{position size} = \frac{f^*}{2} \cdot \text{capital} \tag{22}$$

Volatility scaling:

$$\text{size}_{\text{adjusted}} = \text{size}_{\text{base}} \cdot \frac{\sigma_{\text{target}}}{\sigma_{\text{current}}} \tag{23}$$

Drawdown scaling:

$$\text{size}_{\text{DD}} = \text{size}_{\text{base}} \cdot \max\left(0.1, 1 - \frac{\text{DD}_{\text{current}}}{\text{DD}_{\text{max}}}\right) \tag{24}$$

Homeostatic correction:

$$\Delta\text{allocation} = K_p \cdot (\text{target} - \text{current}) + K_d \cdot \frac{d(\text{target} - \text{current})}{dt} \tag{25}$$

## 2.8 Cerebellum: Motor Control & Execution

### 2.8.1 Neuroscience Background

The cerebellum coordinates fine motor control, learns procedural skills, and predicts sensory consequences of actions (forward models).

### 2.8.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/cerebellum/`
**Components:**

- **Execution**: Order routing, TWAP/VWAP algorithms
- **Impact**: Almgren-Chriss optimal execution
- **Forward Models**: Latency compensation, fill prediction
- **Error Correction**: PID control, adaptive feedback

**Key Responsibilities:**

1. Route orders to exchanges with minimal slippage
2. Predict and minimize market impact
3. Compensate for execution latency (Smith predictor)
4. Learn from execution errors and adapt

**Mathematical Formulation:**
Almgren-Chriss optimal trajectory:

$$x_t = X \cdot \frac{\sinh(\kappa(T-t))}{\sinh(\kappa T)}, \quad \kappa = \sqrt{\frac{\eta\sigma}{\tau}} \tag{26}$$

Market impact:

$$\text{Impact} = \eta \cdot \sigma \cdot \sqrt{\frac{v}{V_{\text{avg}}}} \tag{27}$$

Smith predictor (latency compensation):

$$u(t) = K_c \left[ e(t) + \frac{1}{\tau_I} \int e(\tau) d\tau + \tau_D \frac{de(t)}{dt} \right] + \hat{p}(t + \Delta t) \tag{28}$$

Execution error:

$$\epsilon_{\text{exec}} = |p_{\text{actual}} - p_{\text{predicted}}| \tag{29}$$

## 2.9 Visual Cortex: Pattern Recognition & Vision

### 2.9.1 Neuroscience Background

The visual cortex processes images hierarchically: V1 detects edges, V2 detects shapes, V4 detects objects. It implements hierarchical feature extraction.

### 2.9.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/visual_cortex/`

**Components:**

- **Eyes**: Data ingestion, preprocessing, streaming
- **GAF**: Gramian Angular Fields (GASF, GADF, DiffGAF)
- **ViViT**: Video Vision Transformer for spatiotemporal patterns
- **Visualization**: UMAP, GradCAM, saliency maps

**Key Responsibilities:**

1. Ingest and preprocess raw market data
2. Transform time series to visual manifolds (GAF)
3. Extract spatiotemporal patterns (ViViT)
4. Visualize learned representations (UMAP)

**Mathematical Formulation:**
GAF normalization:

$$\tilde{x}_i = \tanh\left(\frac{x_i - \min(X)}{\max(X) - \min(X) + \epsilon} \cdot \alpha + \beta\right) \tag{30}$$

GASF:

$$\text{GASF}_{i,j} = \cos(\phi_i + \phi_j), \quad \phi_i = \arccos(\tilde{x}_i) \tag{31}$$

GADF:

$$\text{GADF}_{i,j} = \sin(\phi_i - \phi_j) \tag{32}$$

ViViT patch embedding:

$$\mathbf{z}^{(0)}_{f,i,j} = \mathbf{E} \cdot \text{flatten}(\mathcal{V}_{f,i:i+P,j:j+P}) + \mathbf{p}_{f,i,j} \tag{33}$$

## 2.10 Integration: Brainstem & Global Coordination

### 2.10.1 Neuroscience Background

The brainstem controls basic life functions, arousal/sleep cycles, and global state coordination. It's the "operating system" of the brain.

### 2.10.2 Trading Implementation

**Directory:** `src/janus/neuromorphic/integration/`
**Components:**

- **Workflow**: State machine orchestration
- **State**: Global state management, message bus
- **API**: REST, gRPC, WebSocket interfaces
- **Engine**: Wake-sleep cycle coordination

**Key Responsibilities:**

1. Coordinate wake (Forward) and sleep (Backward) cycles

2. Manage global system state
3. Route messages between brain regions
4. Expose external APIs

# 3 Information Flow Diagrams

## 3.1 Wake State (Forward Service)

```
Market Data → Visual Cortex (GAF/ViViT) → Thalamus (Fusion)
                                             ↓
                                          Cortex (Manager)
                                             ↓
                                          Hippocampus (Worker)
                                             ↓
                                          Basal Ganglia (Actor-Critic)
                                             ↓
                                          Prefrontal (LTN Check)
                                             ↓
                                          Amygdala (Fear Check) ──→ Circuit Breaker?
                                             ↓
                                          Hypothalamus (Size Adjust)
                                             ↓
                                          Cerebellum (Execute Order)
                                             ↓
                                          Exchange
```

## 3.2 Sleep State (Backward Service)

```
Hippocampus (Episodic Buffer) → SWR Replay (10-20x speed)
                                   ↓
                                Prioritized Sampling
                                   ↓
                                Basal Ganglia (Update Critic)
                                   ↓
                                Prefrontal (Update LTN)
                                   ↓
                                Cortex (Schema Consolidation)
                                   ↓
                                Long-term Memory (Qdrant)
```

# 4 Implementation Guide

## 4.1 Directory Structure

```
src/janus/neuromorphic/
├── lib.rs                    # Main library entry point
├── common/                   # Shared types and utilities
├── cortex/                   # Strategic planning & LTM
│   ├── manager/             # Feudal RL manager
│   ├── memory/              # Consolidation, schemas
│   └── planning/            # Scenario analysis
├── hippocampus/             # Episodic memory & replay
│   ├── worker/              # Feudal RL worker
│   ├── replay/              # PER buffer
│   ├── episodes/            # Trade sequences
│   └── swr/                 # Sharp wave ripples
├── basal_ganglia/           # Action selection & RL
│   ├── actor/               # Policy network
│   ├── critic/              # Value network
│   ├── praxeological/       # Go/No-Go signals
│   └── selection/           # Action selection
├── thalamus/                # Attention & fusion
│   ├── attention/           # Cross-attention
│   ├── gating/              # Sensory gates
│   ├── routing/             # Information routing
│   └── fusion/              # Multimodal fusion
├── prefrontal/              # Logic & compliance
│   ├── ltn/                 # Logic Tensor Networks
│   ├── conscience/          # Compliance rules
│   ├── planning/            # Goal decomposition
│   └── goals/               # Goal management
├── amygdala/                # Fear & circuit breakers
│   ├── fear/                # FNI-RL network
│   ├── vpin/                # Toxicity detection
│   ├── circuit_breakers/    # Kill switch
│   └── threat_detection/    # Anomaly detection
├── hypothalamus/            # Homeostasis & risk
│   ├── homeostasis/         # Balance tracking
│   ├── position_sizing/     # Kelly, vol scaling
```

```
│   ├── risk_appetite/      # Dynamic tolerance
│   └── energy/             # Capital allocation
├── cerebellum/             # Motor control & execution
│   ├── execution/          # Order routing
│   ├── impact/             # Almgren-Chriss
│   ├── forward_models/     # Latency compensation
│   └── error_correction/   # PID control
├── visual_cortex/          # Pattern recognition
│   ├── eyes/               # Data ingestion
│   ├── gaf/                # GAF transformation
│   ├── vivit/              # ViViT model
│   └── visualization/      # UMAP, GradCAM
└── integration/            # System coordination
    ├── workflow/           # State machines
    ├── state/              # Global state
    ├── api/                # External APIs
    └── engine/             # Orchestration
```

## 4.2 Implementation Checklist

1. **Phase 1: Core Infrastructure (Weeks 1-2)**
   - ☐ Set up neuromorphic module structure
   - ☐ Implement common types and error handling
   - ☐ Create inter-region message bus
   - ☐ Set up integration/engine orchestrator
2. **Phase 2: Visual Processing (Weeks 3-4)**
   - ☐ Implement Visual Cortex data ingestion
   - ☐ Implement GAF transformation (GASF, GADF)
   - ☐ Integrate ViViT model (ONNX or tch-rs)
   - ☐ Add UMAP visualization
3. **Phase 3: Decision Making (Weeks 5-7)**
   - ☐ Implement Basal Ganglia Actor-Critic
   - ☐ Implement Prefrontal LTN constraints
   - ☐ Implement Thalamus fusion mechanisms

- ☐ Connect visual → decision pipeline

4. **Phase 4: Memory Systems (Weeks 8-10)**
   - ☐ Implement Hippocampus episodic buffer
   - ☐ Implement Prioritized Experience Replay
   - ☐ Implement Cortex schema consolidation
   - ☐ Implement SWR compressed replay
5. **Phase 5: Safety & Control (Weeks 11-12)**
   - ☐ Implement Amygdala fear network
   - ☐ Implement circuit breakers and kill switch
   - ☐ Implement Hypothalamus homeostasis
   - ☐ Implement Cerebellum execution control
6. **Phase 6: Integration & Testing (Weeks 13-14)**
   - ☐ Connect all brain regions
   - ☐ Implement wake-sleep cycle coordination
   - ☐ End-to-end integration tests
   - ☐ Performance optimization

# 5 Architectural Invariants

## 5.1 Safety-Critical Invariants

1. **Amygdala Override**: Fear system ALWAYS overrides all other regions
2. **Prefrontal Veto**: LTN constraints MUST block non-compliant actions
3. **No Panic**: No `panic!()`, `unwrap()`, or `expect()` in production code
4. **Fail-Safe**: Circuit breakers must be fail-safe (default to HALT)
5. **Homeostasis**: Cash reserves must never fall below 20%

## 5.2 Performance Invariants

1. **Forward Latency**: Visual Cortex → Decision <100ms
2. **Backward Throughput**: Process >10k experiences per sleep cycle
3. **Memory Efficiency**: Hippocampal buffer <10k transitions (FIFO eviction)
4. **Parallel Processing**: Brain regions process concurrently

## 5.3 Learning Invariants

1. **Dual Timescale**: Fast hippocampal learning, slow cortical consolidation
2. **Recall Gating**: Cortical updates gated by recall strength AND logic validity
3. **Priority Replay**: Replay prioritized by TD-error + logic violations + reward
4. **Schema Formation**: Clusters detected via UMAP + DBSCAN

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