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

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

No-Go signal (indirect pathway):
$$\mathsf{NoGo}(a) = \text{sigmoid}(\mathbf{W}_{\text{indirect}}[\mathbf{h}(s); \mathsf{risk}; \mathsf{VPIN}]) \tag{10}$$

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

## 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:

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

Gating scalar:

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

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:

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

Łukasiewicz conjunction:

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

Wash sale constraint:

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

Satisfiability:

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

## 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 co-ordination. 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
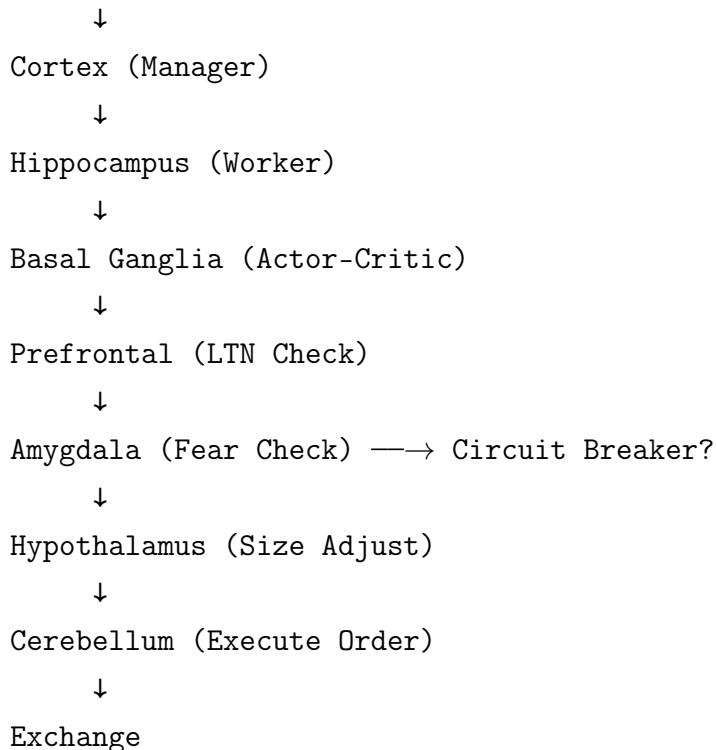
**Key Responsibilities:**

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

2. Manage global system state

3. Route messages between brain regions

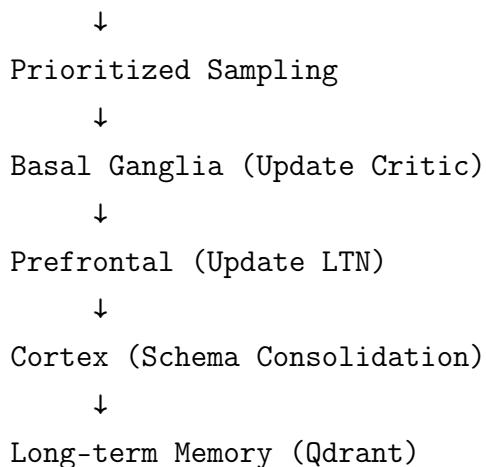4. Expose external APIs

# 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 $\rightarrow$ 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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