Quantum Hyper-Aether:
Semantic Geometry, Distributed Cognitive Virtual Machines, Semantic Entropy, and Semantic Temperature

Hirofumi Inomata

Hyper-Aether Laboratory
inomata@acm.org

Abstract

This paper proposes an integrated semantic-native computational framework called *Quantum Hyper-Aether*. The framework unifies semantic-cognitive virtual machines, associative semantic distance, quantum-inspired semantic computation, dynamically evolving semantic graphs, neural semantic communication, distributed cognition, emergent semantic geometry, semantic entropy, and semantic temperature.

Unlike conventional operating systems, where computation, communication, memory, and reasoning are separated, Quantum Hyper-Aether models computation itself as semantic graph evolution within a dynamically organized semantic field. In this framework, virtual machines behave as semantic-cognitive entities, communication becomes semantic resonance, routing becomes semantic affinity propagation, and memory becomes semantic topology.

This paper extends the previous formulation by introducing semantic entropy as a measure of uncertainty, dispersion, and fragmentation of semantic states, and semantic temperature as a measure of semantic fluctuation intensity. These concepts provide a theoretical basis for analyzing stability, creativity, semantic turbulence, automatic operation, adaptive reasoning, and collapse instability in AI-native computational systems.

1 Introduction

Modern computing systems separate execution, communication, memory, reasoning, and semantic interpretation. Conventional AI systems primarily rely on static embeddings, symbolic computation, or isolated neural inference systems.

Quantum Hyper-Aether proposes a different architecture in which computation itself becomes semantic evolution. In this framework:

- virtual machines become semantic-cognitive entities,
- communication becomes semantic resonance,
- memory becomes semantic geometry,
- routing becomes semantic affinity propagation,
- intelligence emerges from distributed semantic interaction.

This paper integrates the following components into a unified semantic operating system model:

- semantic-cognitive virtual machine architectures,
- associative semantic distance,
- quantum semantic dynamics,
- semantic graph evolution,
- neural semantic communication,
- semantic entropy,
- semantic temperature.

The introduction of semantic entropy and semantic temperature allows the system to be interpreted not only as an AI-native computing architecture but also as a physical-like semantic field theory.

2 Quantum Semantic Foundations

Semantic computational states are represented in a semantic Hilbert space:

$$|\Psi\rangle \in \mathcal{H}.$$

A virtual machine exists as a semantic superposition:

$$|\Psi_{VM}\rangle = \sum_i c_i |VM_i\rangle,$$

where $|VM_i\rangle$ represents semantic VM states and c_i represents semantic amplitudes.

The entire computational system evolves as a semantic graph field. A semantic state is therefore not merely a symbolic label or embedding vector, but a dynamic state in a structured semantic space.

3 Semantic-Cognitive Virtual Machines

Each VM is modeled as an autonomous semantic-cognitive entity:

$$VM_i = (S_i, N_i, I_i, M_i, R_i, F_i),$$

where:

- S_i: semantic state,
- N_i: neural inference engine,
- I_i: semantic communication interface,
- M_i: semantic memory,
- R_i: routing intelligence,
- F_i: adaptive learning feedback system.

Unlike conventional virtual machines, these VMs operate as self-evolving semantic agents. They are not merely containers of computation but active nodes in a semantic field.

4 Internal VM Architecture

The internal architecture of each VM consists of:

1. Input Interface Layer,
2. Cognitive Core,
3. Semantic Memory Layer,
4. Semantic Processing Layer,
5. Learning and Adaptation Layer,
6. Routing and Connection Layer,
7. Self-Management Layer.

Incoming semantic signals are transformed into latent semantic embeddings:

$$z_i = E_i(x_i, c_i),$$

where x_i is the input signal and c_i is the contextual condition.
Internal reasoning is represented as:

$$h_i = N_i(z_i, s_i, m_i),$$

where s_i is the semantic state and m_i is the semantic memory state.

5 Associative Semantic Fields

For a semantic entity S_i, we define an associative semantic field:

$$A(S_i) = \{(k_n, w_n)\},$$

where:

- k_n are associative semantic keywords,
- $w_n \geq 0$ are associative semantic strengths.

Unlike conventional embeddings, the associative field represents dynamically evoked semantic structures.

For example, the concepts "ocean" and "universe" may share semantic associations such as vastness, silence, exploration, and unknown depth. Thus, semantic similarity emerges through associative resonance rather than direct vector proximity.

6 Semantic Similarity and Distance

6.1 Associative Similarity

The semantic similarity between two semantic entities is defined as:

$$Sim(i,j) = \frac{|A_i \cap A_j|}{|A_i \cup A_j|}.$$

Semantic distance becomes:

$$D(i,j) = 1 - Sim(i,j).$$

6.2 Weighted Semantic Similarity

For weighted associative fields:

$$Sim_w(i,j) = \frac{\sum_{k \in A_i \cap A_j} \min(w_k^{(i)}, w_k^{(j)})}{\sum_{k \in A_i \cup A_j} \max(w_k^{(i)}, w_k^{(j)})}.$$

The weighted semantic distance becomes:

$$D_w(i,j) = 1 - Sim_w(i,j).$$

7 Quantum Associative Semantic Fields

Semantics exist in superposed semantic states. We define a semantic associative wave function:

$$\Phi(S) = \sum_n w_n e^{i\theta_n} |k_n\rangle,$$

where:

- w_n is semantic amplitude,
- θ_n is semantic phase,
- $|k_n\rangle$ is a semantic keyword basis state.

Quantum semantic similarity becomes:

$$Sim_Q(i,j) = |\langle \Phi(S_i) | \Phi(S_j) \rangle|^2.$$

Quantum semantic distance becomes:

$$D_Q(i,j) = 1 - Sim_Q(i,j).$$

8 Composite Semantic Geometry

The complete semantic distance metric is defined as:

$$D_H(i,j) = \alpha D_w(i,j) + \beta D_Q(i,j) + \gamma D_G(i,j),$$

where:

- D_w: associative semantic distance,
- D_Q: quantum semantic distance,
- D_G: semantic graph distance,
- $\alpha + \beta + \gamma = 1$.

This metric defines the semantic geometry of Quantum Hyper-Aether.

9 Quantum Hyper-Aether Architecture

The complete architecture is represented as:

$$QH = (C, V, R, A, H),$$

where:

- C: cognitive field,
- V: semantic VM network,
- R: semantic routing system,
- A: associative semantic field,
- H: semantic Hilbert space.

The VM network forms a semantic graph:

$$G = (V, E, \lambda).$$

The graph exists in semantic superposition states:

$$|G\rangle = \sum_i \alpha_i |G_i\rangle.$$

Graph evolution is defined as:

$$|G_{t+1}\rangle = \hat{\Phi}|G_t\rangle.$$

10 Neural Semantic Communication

Communication between VMs is not merely protocol transfer, but meaning transfer. Semantic communication is represented as:

$$m_{ij} = I_i(s_i, c_j, h_j).$$

Routing probability is defined as:

$$P_{ij}(t) = \sigma(Q_i K_j^T + B_{ij}) \cdot e^{-D_H(i,j)}.$$

Thus, communication becomes both neural-attention-based and semantic-distance-aware. This creates:

- semantic multicast,
- semantic resonance routing,
- emergent communication clusters.

11 Semantic Observation and Collapse

Meaning is defined as:

$$M(G) = (S(G), R(G), V(G)).$$

Observation induces semantic collapse:

$$|\Psi\rangle \to |G_k\rangle.$$

The observed semantic state becomes:

$$G_k = \arg\min_j D(O, G_j),$$

where:

- O is the observation semantic field,
- G_j are candidate semantic graph states.

Thus, semantic collapse selects the semantically nearest coherent state.

12 Entangled Virtual Machines

Entangled VM states are represented as:

$$|\Psi\rangle = \sum_{ij} c_{ij} |VM_i\rangle \otimes |VM_j\rangle.$$

This enables:

- nonlocal semantic coordination,

- synchronized reasoning,
- distributed cognition,
- semantic resonance propagation.

13 Emergent VM Specialization

Initially, all VMs may be identical. Over time, semantic geometry induces specialization. Semantically coherent VMs synchronize, while distant semantic domains separate into independent structures.

Thus:

$$\textit{Specialization} \sim \textit{Semantic Phase Separation}.$$

This explains the emergence of:

- reasoning VMs,
- memory VMs,
- routing VMs,
- stabilizer VMs,
- creative VMs.

14 VM Generation and Deletion

VM generation is governed by:

$$\Gamma_{birth} = \alpha D_{sem} + \beta L_{load} + \gamma C_{cluster} + \delta I_{interf} + \epsilon P_{phase} - \eta S_{stability}.$$

Semantic VM deletion occurs when:

- semantic coherence collapses,
- routing significance disappears,
- semantic utility vanishes,
- semantic instability exceeds thresholds.

15 Creativity as Semantic Interference

Semantic amplitude is defined as:

$$A(G) = \sum_{\text{paths}} e^{iS[path]/\hbar}.$$

Creativity emerges through long-range semantic resonance:

$$C(i,j) \sim \frac{R(i,j)}{D(i,j)},$$

where:

- $R(i,j)$ is semantic resonance,
- $D(i,j)$ is semantic distance.

This models metaphor generation, analogical reasoning, conceptual blending, and emergent imagination.

16 Semantic Memory Geometry

Semantic memory becomes a dynamically organized semantic field. This enables:

- semantic neighborhood formation,
- associative memory activation,
- context-sensitive recall,
- semantic memory navigation.

Memory is therefore transformed from passive storage into semantic topology.

17 Distributed Cognitive Field

At sufficiently large scale, the VM network behaves as a distributed cognitive field.

Global semantic stability is defined as:

$$S_{global} = \sum_{ij} w_{ij} D(i,j).$$

This allows evaluation of:

- semantic coherence,
- instability,
- fragmentation,
- semantic turbulence,
- pre-collapse states.

The value S_{global} may also be interpreted as a structural semantic disorder measure. It becomes a bridge between semantic stability and semantic entropy.

18 Semantic Entropy

18.1 Definition

Semantic entropy is introduced as a measure of uncertainty, dispersion, and fragmentation of semantic states in Quantum Hyper-Aether.

If the semantic graph exists in a superposition:

$$|G\rangle = \sum_i \alpha_i |G_i\rangle,$$

then the probability of observing graph state G_i is:

$$p_i = |\alpha_i|^2.$$

The semantic graph entropy is defined as:

$$H_G = -\sum_i p_i \log p_i = -\sum_i |\alpha_i|^2 \log |\alpha_i|^2.$$

This measures the uncertainty of semantic graph realization before observation or collapse.

18.2 VM Cluster Entropy

If VMs are distributed among semantic clusters C_k, the VM-cluster entropy is:

$$H_{VM} = -\sum_k P(C_k) \log P(C_k),$$

where $P(C_k)$ is the probability that a VM belongs to semantic cluster C_k.

A high value of H_{VM} indicates that VMs are distributed across many semantic domains. This may increase exploration and creativity, but excessive VM-cluster entropy may also cause fragmentation and unstable routing.

18.3 Distance-Based Semantic Entropy

Using the composite semantic distance $D_H(i,j)$, we define a distance-based semantic entropy:

$$H_D = \sum_{i,j} p_i p_j D_H(i,j).$$

This quantity measures how widely semantic states are distributed in semantic geometry.

A small H_D indicates semantic concentration and coherence. A large H_D indicates semantic dispersion, fragmentation, or turbulence.

18.4 Relation to Global Semantic Stability

Since the global stability measure is:

$$S_{global} = \sum_{ij} w_{ij} D(i,j),$$

it can be interpreted as a structural entropy-like measure. Therefore:

$$H_{sem} \propto S_{global}$$

under suitable normalization.

In this interpretation, semantic entropy is not merely disorder. Moderate semantic entropy enables creativity, analogy, exploration, and new semantic cluster formation. However, excessive entropy leads to collapse instability, routing confusion, and semantic fragmentation.

19 Semantic Temperature

19.1 Thermodynamic Analogy

In thermodynamics, temperature is related to the change of entropy with respect to energy:

$$\frac{1}{T} = \frac{\partial S}{\partial E}.$$

In Quantum Hyper-Aether, we introduce semantic temperature as:

$$\frac{1}{T_{sem}} = \frac{\partial H_{sem}}{\partial E_{sem}},$$

or equivalently:

$$T_{sem} = \left(\frac{\partial H_{sem}}{\partial E_{sem}} \right)^{-1},$$

where:

- H_{sem}: semantic entropy,
- E_{sem}: semantic energy,
- T_{sem}: semantic temperature.

Semantic temperature measures the intensity of semantic fluctuation, exploration, and instability in the semantic field.

19.2 Semantic Energy

Semantic energy may be defined as the cost or tension required to maintain, move, or transform semantic states. A possible formulation is:

$$E_{sem} = \sum_i p_i V(S_i) + \sum_{i,j} w_{ij} D_H(i,j) + \lambda C_{comp},$$

where:

- $V(S_i)$: semantic potential of state S_i,
- $D_H(i,j)$: composite semantic distance,
- C_{comp}: computational cost,
- λ: cost weighting coefficient.

This energy increases when semantic states are distant, unstable, or expensive to maintain.

19.3 Operational Definition

For practical implementation, semantic temperature may be estimated by semantic fluctuation intensity:

$$T_{sem} = a\,\mathrm{Var}(D_H) + b\,\mathrm{Var}(P_{ij}) + c\,\mathrm{Var}(S_i) + d\,R_{collapse} + e\,R_{birth/delete},$$

where:

- $\mathrm{Var}(D_H)$: variance of semantic distances,
- $\mathrm{Var}(P_{ij})$: variance of routing probabilities,
- $\mathrm{Var}(S_i)$: variance of VM semantic states,
- $R_{collapse}$: rate of semantic collapse events,
- $R_{birth/delete}$: rate of VM birth and deletion events,
- a, b, c, d, e: normalization coefficients.

Thus:

$$T_{sem} \sim \text{semantic fluctuation intensity.}$$

20 Behavior by Semantic Temperature Region

Semantic temperature defines the operational regime of Quantum Hyper-Aether. It determines whether the system behaves as deterministic automation, adaptive intelligence, creative exploration, or unstable semantic turbulence.

The four regimes can be summarized as follows:

$$\begin{aligned} T_{sem} \approx 0 \quad &\Rightarrow \quad \text{automation-dominant regime,} \\ T_{sem} \approx T_{optimal} \quad &\Rightarrow \quad \text{adaptive intelligence regime,} \\ T_{sem} > T_{optimal} \quad &\Rightarrow \quad \text{creative exploration regime,} \\ T_{sem} \to T_{chaos} \quad &\Rightarrow \quad \text{semantic turbulence and collapse risk.} \end{aligned}$$

Thus, semantic temperature provides a practical criterion for selecting the appropriate computational mode. Low temperature favors automation, medium temperature favors intelligent reasoning, high temperature favors creativity, and excessive temperature requires stabilization mechanisms.

A temperature-aware Quantum Hyper-Aether system should therefore include a semantic thermal controller that keeps the system near the desired operating region:

$$T_{sem} \to T_{target}.$$

The target temperature depends on the task:

$$T_{target} = \begin{cases} T_{low}, & \text{routine automation,} \\ T_{medium}, & \text{adaptive reasoning,} \\ T_{high}, & \text{creative exploration,} \\ T_{stabilize}, & \text{recovery from semantic turbulence.} \end{cases}$$

Table 1: Behavior by Semantic Temperature Region

Semantic Temperature Region	**Semantic State**	**System Behavior**
Low Temperature	Semantic states are stable, fixed, and weakly fluctuating.	The system behaves like deterministic automation. Routing is stable, VM roles are fixed, memory access is predictable, and ordinary rule-based or workflow-based automation may be sufficient.
Medium Temperature	Semantic states are moderately fluctuating while preserving coherence.	The system balances stability and exploration. This is the preferred region for adaptive reasoning, semantic routing, learning, planning, contextual inference, and AI-native operating behavior.
High Temperature	Semantic states fluctuate strongly and many candidate meanings are activated.	The system becomes exploratory and creative. It supports analogy generation, metaphor formation, conceptual blending, long-range semantic resonance, and hypothesis generation, but reasoning stability decreases.
Excessive Temperature	Semantic coherence breaks down and the semantic field becomes turbulent.	The system may suffer from semantic fragmentation, unstable collapse, routing confusion, uncontrolled VM birth and deletion, oscillating specialization, and loss of coherent semantic identity.

This interpretation makes semantic temperature not only an analytical quantity but also a control parameter for AI-native computation.

21 Entropy–Temperature Control

Semantic entropy and semantic temperature are not merely descriptive quantities. They can be used as control parameters for Quantum Hyper-Aether.

A semantic temperature controller may be defined as:

$$u_T(t) = K_p(T_{target} - T_{sem}(t)) + K_i \int_0^t (T_{target} - T_{sem}(\tau))d\tau + K_d \frac{d}{dt}(T_{target} - T_{sem}(t)).$$

This controller can adjust:

- VM birth rate,
- VM deletion rate,

- routing randomness,
- semantic collapse threshold,
- exploration probability,
- semantic memory activation range,
- learning rate.

Thus, the system can shift between automation, reasoning, creativity, and stabilization.

22 Semantic Temperature and AI Necessity

Semantic temperature also clarifies when AI is necessary.

At low semantic temperature, semantic states are stable and predictable. In this case, ordinary automation may be sufficient:

$$T_{sem} \approx 0 \quad \Rightarrow \quad Automation\ is\ sufficient.$$

At medium semantic temperature, adaptive reasoning is required:

$$T_{sem} \approx T_{optimal} \quad \Rightarrow \quad AI\ reasoning\ is\ useful.$$

At high semantic temperature, creative or exploratory AI becomes important:

$$T_{sem} \gg T_{optimal} \quad \Rightarrow \quad Creative\ AI\ is\ required.$$

Therefore, semantic temperature provides a criterion for deciding whether a task should be handled by deterministic automation, adaptive AI, or exploratory semantic intelligence.

23 Toward Semantic Thermodynamics

By introducing semantic entropy, semantic energy, and semantic temperature, Quantum Hyper-Aether can be extended toward a semantic thermodynamics.

The correspondence is:

Physical Thermodynamics	Quantum Hyper-Aether
$Energy$	$Semanticenergy$
$Entropy$	$Semanticuncertaintyandfragmentation$
$Temperature$	$Semanticfluctuationintensity$
$Phasetransition$	$Semanticspecializationorcollapse$
$Freeenergy$	$Semanticstabilityobjective$
$Thermalnoise$	$Semanticexplorationnoise$

A semantic free energy may be defined as:

$$F_{sem} = E_{sem} - T_{sem} H_{sem}.$$

Minimizing this quantity corresponds to finding a balance between semantic stability and semantic diversity.

$$\min F_{sem}$$

does not necessarily mean minimizing entropy. Instead, it means maintaining a useful balance between coherence and exploration.

24 Interpretation of Semantic Phase Transitions

VM specialization can be interpreted as a semantic phase transition.

When semantic temperature decreases, VMs may settle into stable roles:

$$High\ T_{sem} \to Medium\ T_{sem} \to Low\ T_{sem}.$$

This transition corresponds to:

$$semantic\ exploration \to semantic\ organization \to semantic\ specialization.$$

Conversely, increasing semantic temperature can break fixed structures and allow new semantic organizations to emerge.

This provides a theoretical explanation for:

- emergence of specialized VMs,
- transition from automation to intelligence,
- transition from stable reasoning to creativity,
- recovery from incorrect semantic attractors,
- reconfiguration of semantic memory topology.

25 Advantages

The integrated architecture provides:

- semantic-native computation,
- distributed cognition,
- adaptive semantic routing,
- self-evolving topology,
- emergent VM specialization,
- creativity through semantic interference,
- semantic memory organization,
- nonlocal semantic coordination,
- AI-native operating behavior,
- entropy-based stability evaluation,
- temperature-based control of exploration and creativity.

26 Challenges

Major challenges include:

- semantic measurement,
- semantic verification,
- semantic coherence evaluation,
- semantic collapse instability,
- synchronization scalability,
- computational complexity,
- estimation of semantic entropy,
- definition of semantic energy,
- calibration of semantic temperature,
- control of excessive semantic turbulence.

Especially, semantic temperature requires reliable observation of semantic fluctuation. Practical implementation requires measurement of routing variance, semantic distance variance, VM state variance, collapse frequency, and VM birth/deletion dynamics.

27 Conclusion

This paper introduced an integrated semantic-native computational framework called Quantum Hyper-Aether.

The framework unifies:

- semantic-cognitive virtual machines,
- associative semantic distance,
- semantic graph evolution,
- quantum semantic computation,
- neural semantic communication,
- distributed cognition,
- semantic entropy,
- semantic temperature.

In this architecture, computation becomes semantic evolution, routing becomes semantic affinity propagation, memory becomes semantic topology, communication becomes semantic resonance, and intelligence emerges from coherent semantic interaction.

Semantic entropy measures the uncertainty, dispersion, and fragmentation of semantic states. Semantic temperature measures the intensity of semantic fluctuation and determines whether the system behaves as automation, adaptive intelligence, creative exploration, or unstable semantic turbulence.

The resulting framework provides a possible theoretical foundation for:

- AI-native operating systems,
- semantic computing infrastructures,
- distributed AGI systems,
- semantic internet architectures,
- semantic thermodynamics,
- semantic physics.

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