

Fundamental Interaction Language

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Chapter 1

Foundations and Semantic Constants

1.1 The Information–Observation–Language (I–O–L) Triad

Modern knowledge systems reveal a recurring motif: comprehension requires only the *differences* between two bodies of knowledge, not their entirety. We formalise this with the **Information–Observation–Language triad**

$$(\mathcal{I}, \mathcal{O}, \mathcal{L}) = (\mathcal{I}, \mathcal{O}, \mathcal{L}), \quad (1.1)$$

where \mathcal{I} denotes possible information states, \mathcal{O} the set of admissible observations, and \mathcal{L} the symbolic language capable of encoding both. Minimal "bridges" between domains are implemented by Local Language Constructors (LLCs), treated in Chapter ??.

1.2 Foundational Postulates

Postulate F1 (Semantic locality). Any act of communication factors through a finite sub-language $B \subseteq \mathcal{L}$ such that $E \otimes B \cong \mathcal{L}$, with E the receiver's existing language fragment.

Postulate F2 (Minimal bridges). Among all such B , natural communication selects one that minimises $|B|$.

Postulate F3 (Hierarchical union). Languages compose by hierarchical union and the semantic density ρ is non-decreasing under this union.

1.3 Semantic Constants

We introduce two universal constants:

c_s the *semantic light-speed*, bounding information propagation in a knowledge graph:

$$d_G(v_1, v_2) \leq c_s \Delta t. \quad (1.2)$$

\hbar_s the *semantic Planck constant*, appearing in an uncertainty relation between discovery and invention operators:

$$\Delta D \Delta I \geq 12 \hbar_s. \quad (1.3)$$

Convenient units set $c_s = \hbar_s = 1$; deviations measure complexity.

1.4 Road-map

This chapter establishes notation for the remainder of the book. Chapter ?? develops the geometric view (c_s as cone slope), Chapter ?? derives global limits from Eq. eq:sem-uncertainty, Chapter ?? treats drift and masks, and Chapter ?? links the constants to physical information bounds.

Take-away. The triad $(\mathcal{I}, \mathcal{O}, \mathcal{L})$ and constants (c_s, \hbar_s) provide an irreducible substrate on which all higher FIL structures are built.

Chapter 2

Semantic Geometry

2.1 Semantic Light-Cones

In a knowledge graph $G = (V, E)$ we define the *semantic distance* $d_G(v_1, v_2)$ as the minimal edge-weighted path length between two concept vertices. Postulate F1 implies that information flow is bounded by the constant c_s introduced in Chapter ??:

$$d_G(v_1, v_2) \leq c_s \Delta t. \quad (2.1)$$

Points satisfying equality trace **semantic light-cones**. They encode the frontier beyond which two agents cannot reach mutual comprehension within Δt .

Propagation kernel. Let $K_t(v)$ denote the reachable set from v in time t . A discrete propagator is $P_t = 1_{d_G \leq c_s t}$.

2.2 Informational Curvature

Light-cone slope alone does not capture *semantic gravitation*—the tendency of dense subgraphs to attract interpretive trajectories. We introduce an *informational curvature tensor* \mathcal{K} via the deviation of geodesics in G :

$$\delta^2 d_G = -\mathcal{K}(\gamma, \dot{\gamma}) d\sigma^2. \quad (2.2)$$

Positive curvature corresponds to semantic "mass" and appears near high mutual-information clusters. See [?](§2) for the full derivation.

Example – category junction

Two dense languages L_1, L_2 joined by a minimal LLC bridge B create negative curvature in the bridge (saddle) and positive curvature inside each language core.

2.3 Computational Spacetime Correspondence

Mapping Eq. eq:semantic-cone onto a Turing tape with physical delays τ , we recover the computational light-speed bound $c_s \approx 1/\tau$ [?]. Informational curvature then corresponds to non-uniform memory access latencies—regions of high semantic mass behave as RAM “black holes”.

2.4 Meta-Law and Quantisation

FL_Field Meta-Law postulates a universal action principle in information space. Quantising small oscillations of d_G about a ground state yields a discrete spectrum analogous to normal modes in Riemannian geometry. This motivates the uncertainty relation derived in Eq. (??).

Take-away. The geometry of semantic light-cones and informational curvature generalises relativistic causality to knowledge systems, setting the stage for global bounds (Chapter ??) and dynamical drift analysis (Chapter ??).

Chapter 3

Informational Bounds

3.1 Bekenstein-like Entropy Limit for Language

The classical Bekenstein bound [?] constrains the maximum entropy S of physical matter in a region of radius R and energy E by $S \leq 2\pi kER/\hbar c$. In the FIL setting, tokens carry informational mass and the analogue becomes

$$H(\mathcal{L}) \leq 2\pi k_s E_{\mathcal{L}} R_{\mathcal{L}} / \hbar_s, \quad (3.1)$$

where $E_{\mathcal{L}}$ is the cumulative energetic cost of storing the language fragment and $R_{\mathcal{L}}$ its semantic diameter.

Interpretation. If H exceeds this limit, further compression (via LLC bridges) or hierarchical segmentation is required.

3.2 Finite Knowledge Bounds

Let $G = (V, E)$ be a directed knowledge graph with path entropy H_P and symbol complexity C_s . finiteknowledgebounds2025 derive upper and lower compression bounds

$$\frac{|V|}{\log C_s} \leq H_P \leq |E| \log C_s. \quad (3.2)$$

We adopt the lower bound as the *finite knowledge bound* (FKB) for any segment.

3.2.1 Prime-Encoding Lower Bound

Prime-encoding of edge labels achieves the lower bound asymptotically; see Appendix ??.

3.2.2 Voronoi Capacity Upper Bound

Semantic Voronoi cells give a geometric ceiling; we revisit this in Chapter ?? when studying drift fields.

3.3 Acceleration Constraint

acceleration2025 show that rapid semantic updates imply an *acceleration cost*

$$a_{\mathcal{L}} \equiv \frac{d^2 H}{dt^2} \leq c_s^2 / \ell_{\min}, \quad (3.3)$$

with ℓ_{\min} the minimum edge length. This links light-cone slope (c_s) to second-order dynamics.

3.4 Big Bang as Information Phase Transition

The cosmological Big Bang is recast as a phase transition where $H \rightarrow 0$ while $dH/dt \rightarrow \infty$. Under FKB this corresponds to the creation of the minimal language fragment required for any subsequent evolution.

3.5 Road-map

Informational limits set the stage for Chapter ??, where drift and masks operate within these bounds, and Chapter ??, which ties them to particle-level information exchange.

Chapter 4

Dynamics, Drift, and Mask-Based Stabilisation

4.1 Diagnosing Semantic Drift

Let $\delta_k(n)$ denote the *drift magnitude* of concept k after n network layers. Following SSR_{Draft3}, we define $\delta_k(n) = \frac{\|P_k^n - P_k^0\|}{\|P_k^0\|}$, (4.1) where P_k^n is the perturbation field of concept k at depth n . The *shadow depth* Δ_k^n is the first layer $m > n$ such that $\delta_k(m) < \varepsilon$. A rising sequence Δ_k^n indicates unstable semantics.

4.2 Mask Evolution Operator

Dynamic masks M_k^n are injected at layer n to probe drift. The **Mask Evolution Operator** (MEO) propagates masks across depth:

$$T_1^n : M_k^1 \mapsto M_k^n, \quad T_1^n = T_{n-1}^n \circ \dots \circ T_1^2. \quad (4.2)$$

The *error tensor*

$$E_k^n = M_k^n - T_1^n(M_k^1) \quad (4.3)$$

serves as a drift-diagnostic: $\|E_k^n\| \rightarrow 0$ implies layer stability.

4.3 Gaussian-Mixture View of Observation

Observation tokens are embedded as weighted Gaussian mixtures $GMM(w_i, \mu_i, \Sigma_i)$. Overlap of components predicts hallucination regions. The mixture distance introduces a probabilistic refinement of the drift metric:

$$d_{GMM}(p, q) = 1 - \sum_i \sqrt{w_i^{(p)} w_i^{(q)}} e^{-12 \Delta \mu_i^\top \Sigma_i^{-1} \Delta \mu_i}. \quad (4.4)$$

4.4 Perturbation Cellular Automata

Discrete propagation of truth-wavefronts may be simulated by a perturbation cellular automaton (PCA) on the concept graph $G = (V, E)$. Each cell updates via

$$s_{t+1}(v) = f(s_t(v), (s_t(u))_{u \in N(v)}), \quad (4.5)$$

where f conserves a local *semantic energy* to satisfy the bound $d_G \leq c_s \Delta t$.

4.5 The Nibbler Algorithm

1. Initialise discovery state D_0 and pattern set P_0 .
2. (Discovery) $D_{t+1} \leftarrow D_t + \text{NibblerStep}(D_t)$.
3. (Pattern) $P_{t+1} \leftarrow \text{MetaPattern}(P_t, D_{t+1})$.
4. Repeat until ΔD and ΔP fall below thresholds.

The interface kernel

$$k_{NI}(x, y) = \alpha k_D(x, y) + (1 - \alpha) k_P(x, y) \quad (4.6)$$

controls the discovery–pattern balance.

4.6 Integration with the UIL Framework

Integration_{UIL} extends the graph model to include confidence $c(\omega)$ and security $\lambda(\omega)$. The drift-aware propagation rule becomes

$$\Delta(v_i, v_{i+1}) = \min(\text{infochange} \mid \lambda(v_{i+1}) \geq \lambda_{\min}, c(\omega) \geq c_{\min}). \quad (4.7)$$

4.7 Outlook

This chapter introduced dynamical machinery that preserves the semantic constants while allowing adaptive evolution. Chapter ?? maps these operators to physical processes—e.g. interferometric stabilisation in the InterferoShell.

Take-away. Mask evolution, GMM observation, and Nibbler search conspire to keep drift bounded without violating the informational limits of Chapter ??.

Chapter 5

Physical and Computational Correspondence

5.1 Particles as Information Events

Each fundamental interaction instantiates new information [?]. Let $S(t) = \{p_i, E_{ij}\}$ denote the quantum state at time t . A collision $T : S(t) \rightarrow S(t+1)$ increases the descriptive complexity

$$\Delta I = I(S(t+1)) - I(S(t)) \leq kE. \quad (5.1)$$

This yields a conservation-of-information principle analogous to energy conservation in QFT.

5.2 Computational Relativity Analogy

5.2.1 Complexity Time-Dilation

Landauer–Bremermann bounds suggest that executing N logical operations on mass m requires a minimum proper time $\Delta\tau \geq N\hbar/(mc^2)$. Interpreting complexity as curvature we obtain a metric on algorithmic spacetime:

$$ds^2 = -\left(1 - \frac{2GC}{c^2 r}\right)c^2 dt^2 + \left(1 - \frac{2GC}{c^2 r}\right)^{-1} dr^2 + r^2 d\Omega^2, \quad (5.2)$$

with C the local Kolmogorov complexity density.

5.2.2 Physical Foundations of Computational Light-Speed

Chapter 3 of [?] derives a physical upper speed of algorithmic propagation that coincides with the semantic constant c_s introduced in Chapter ??.

5.3 Computational Spacetime Geometry

Information flow defines a causal set \mathcal{C} whose Hasse diagram embeds into the knowledge graph G . Curvature of \mathcal{C} matches informational curvature κ of Section ??, closing the semantic-physical loop.

5.4 InterferoShell Hardware Sketch

Architecture. A ring interferometer couples two superconducting qubits via a variable-delay photonic path.

Function. Physical phase shifts implement the mask evolution operator T_1^n in hardware, stabilising drift.

Throughput. Operational bandwidth is limited by the physical light-speed bound c and translates to c_s cycles in semantic time.

5.5 Prime Path Encoding for Graph Compression

Path-encoding maps concept trajectories to unique prime products $\pi(P) = \prod p_i^{n_i}$. The length satisfies

$$|P| \leq O(\log \pi(P)), \quad (5.3)$$

providing asymptotically optimal storage ([?]).

5.6 Discussion and Future Work

Links between semantic and physical bounds suggest experimental tests:

1. Measure drift suppression in InterferoShell prototypes.
2. Investigate Hawking-like emission at semantic black-hole horizons where $\rho \rightarrow \infty$.
3. Extend computational relativity metrics to non-commutative graph geometries.

Take-away. Physical interaction, algorithmic complexity, and semantic structure obey the same limiting principles, unifying FIL with fundamental physics.