

Structured Knowledge Accumulation (SKA): The Trilogy

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This year, the **Structured Knowledge Accumulation (SKA)** framework introduced a unifying mathematical principle that connects *information theory, physics, and geometry* through the continuous evolution of knowledge. Instead of viewing intelligence as optimization or backpropagation, SKA reveals it as a natural process of *entropy-guided organization* — a forward-only flow of information where knowledge accumulates along the path of minimal uncertainty.

Part I – The Foundation

Structured Knowledge Accumulation: An Autonomous Framework for Layer-Wise Entropy Reduction in Neural Learning

SKA begins with the discovery that learning can be expressed as a *law of entropy reduction*. Each neural layer evolves autonomously, aligning its knowledge tensor Z with the decision probability shift D through forward-only dynamics:

$$H = -\frac{1}{\ln 2} \int z dD$$

This formulation establishes entropy as the central invariant of learning. Neural systems no longer require backpropagation; they self-organize by reducing uncertainty step by step.

Part II – The Dynamics

Structured Knowledge Accumulation: The Principle of Entropic Least Action in Forward-Only Neural Learning

The second paper elevates SKA to the level of physical law. By interpreting the learning rate as a temporal differential, SKA reveals that the evolution of knowledge follows the *principle of entropic least action*:

$$L(z, \dot{z}) = -z \sigma(z)(1 - \sigma(z)) \dot{z}$$

The Euler–Lagrange equation,

$$\frac{d}{dt} \left(\frac{\partial L}{\partial \dot{z}} \right) - \frac{\partial L}{\partial z} = 0,$$

collapses to an identity $0 = 0$, showing that the system’s trajectory is *intrinsically optimal*. Learning is thus a natural law of motion in information space — not an optimization problem, but an entropic flow.

Part III – The Geometry

Structured Knowledge Accumulation: Geodesic Learning Paths and Architecture Discovery in Riemannian Neural Fields

The third work extends SKA to continuous neural fields. By introducing neuron density $\rho(r)$ and local entropy $h(r)$, the neural medium becomes a *Riemannian information manifold* with metric:

$$g_{ij}(r) = \alpha (\nabla h)_i (\nabla h)_j + \beta (\nabla \rho)_i (\nabla \rho)_j + \gamma \delta_{ij}$$

Knowledge propagates along *geodesic trajectories* that minimize information distance:

$$\frac{d^2 x^i}{dt^2} + \Gamma_{jk}^i \frac{dx^j}{dt} \frac{dx^k}{dt} = 0,$$

revealing architectures that are not designed but discovered — the natural geometry of entropy flow.

The Unified Vision

From **entropy** to **dynamics** to **geometry**, the SKA trilogy traces the full trajectory of intelligence:

Learning is not the correction of error — it is the progressive organization of knowledge along the path of minimal entropy.

The Structured Knowledge Accumulation framework bridges information theory, variational physics, and differential geometry into a single coherent model of cognition. It offers a foundation for forward-only, real-time, and energy-efficient intelligence — a path toward truly autonomous systems that learn as nature does: continuously, coherently, and without backtracking.

Mathematical Unity

The beauty of SKA lies in its perfect coherence. Each paper is not an extension but a *dimensional unfolding* of the same fundamental law:

- **Paper I:** defines the scalar invariant of learning — entropy as the measurable relation between knowledge and decision.
- **Paper II:** lifts this invariant into time — learning as the least-action trajectory in entropy space.
- **Paper III:** lifts it further into geometry — entropy as curvature guiding information along geodesics.

The structure forms a complete mathematical cycle:

$$H \Rightarrow L \Rightarrow g_{ij}$$

where entropy (H) generates the Lagrangian (L), and the Lagrangian gives rise to the Riemannian metric (g_{ij}). This closure mirrors the great symmetries of physics — from potential to motion to geometry — but here applied to information and cognition.

SKA thus reveals that the act of learning, when seen from first principles, is the natural continuation of the laws of physics into the informational domain. It unites Shannon’s entropy, Lagrange’s action, and Riemann’s geometry into a single law of knowledge accumulation.

References

- Bouarfa Mahi, *Structured Knowledge Accumulation: An Autonomous Framework for Layer-Wise Entropy Reduction in Neural Learning*, arXiv:2503.13942 (2025)
- Bouarfa Mahi, *Structured Knowledge Accumulation: The Principle of Entropic Least Action in Forward-Only Neural Learning*, arXiv:2504.03214 (2025)
- Bouarfa Mahi, *Structured Knowledge Accumulation: Geodesic Learning Paths and Architecture Discovery in Riemannian Neural Fields*, November 2025