Semantic Recursion as Entropic Smoothing: A Field-Theoretic Model of Intelligence in RSVP

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Abstract

Intelligence emerges not solely from neural computation but from recursive semantic compression and entropy reduction induced by linguistic, architectural, social, and technological scaffolding. Using the Relativistic Scalar Vector Plenum (RSVP) framework, we model these as structured deformations of a cognitive manifold, with implications for cognitive science, artificial intelligence, neuroscience, and cultural evolution.

1 Introduction

The central question of this paper is: What makes intelligence efficient and scalable in humans? Traditional neurocentric views of intelligence, which emphasize internal neural computation, are limited in capturing the distributed and culturally scaffolded nature of cognition. We introduce the Relativistic Scalar Vector Plenum (RSVP) theory, a field-based model governed by partial differential equations (PDEs), to propose that intelligence arises through semantic recursion acting as entropic smoothing on a structured cognitive manifold.

This paper develops a multilayer model comprising four key scaffolding layers:

- $\mathcal{L}_1$: Language
- $\mathcal{L}_2$: Built Environment
- $\mathcal{L}_3$: Social Norms
- $\mathcal{L}_4$: Technological Interfaces

These layers collectively reduce cognitive entropy and enhance efficient navigation of the cognitive manifold.

2 Mathematical Foundations of RSVP Cognition

2.1 The RSVP Field Triplet

The RSVP framework defines intelligence through three interrelated fields:

- Scalar field Φ: Represents the semantic potential landscape.
- Vector field $\vec{v}$: Represents directed attention or semantic flow.
- Entropy field $\mathcal{S}$: Represents local uncertainty or informational complexity.

2.2 Dynamic Equations

The dynamics of these fields are governed by the following PDEs:

$$\partial_t \Phi = -\nabla \cdot \vec{v} + \alpha_1 \Delta \Phi + f(\Phi, \vec{v}, \mathcal{S}), \tag{1}$$

$$\partial_t \vec{v} = -\nabla \Phi + \alpha_2 \nabla \times (\nabla \times \vec{v}) + g(\Phi, \vec{v}, \mathcal{S}), \tag{2}$$

$$\partial_t \mathcal{S} = -\vec{v} \cdot \nabla \mathcal{S} + \alpha_3 \Delta \mathcal{S} + h(\Phi, \vec{v}), \tag{3}$$

where $\alpha_1, \alpha_2, \alpha_3$ are diffusion coefficients, and f, g, h are nonlinear interaction terms.

2.3 Intelligence as Manifold Traversal

Intelligence $\mathcal{I}$ is formalized as efficient navigation of the cognitive manifold $\mathcal{M}$ under bounded sensory input:

$$\mathcal{I} = \int_{\Omega \subset \mathcal{M}} [-\nabla \mathcal{S}(x) + \lambda_1 \cdot \nabla \cdot \vec{v} + \lambda_2 \cdot \Delta \Phi] \, dx, \tag{4}$$

where λ_1, λ_2 are weighting parameters, and Ω is a subset of the manifold.

3 Semantic Labels as Recursive Compression Operators

3.1 Conceptual Role of Labels

Words and concepts act as semantic operators that compress experience into manageable units. Each label ℓ induces a local deformation of the cognitive manifold.

3.2 Field-Theoretic Effects of Labels

The effect of a label ℓ on the RSVP fields is given by:

$$\delta_\ell \Phi = -\beta_1 \cdot \chi(\ell), \tag{5}$$

$$\delta_\ell \vec{v} = \beta_2 \cdot \nabla_\ell \Phi, \tag{6}$$

$$\delta_\ell \mathcal{S} = -\beta_3 \cdot |\nabla \Phi|^2 \cdot \Theta(\ell), \tag{7}$$

where $\chi(\ell)$ is a characteristic function of the label, $\Theta(\ell)$ represents context affordance spread, and $\beta_1, \beta_2, \beta_3$ are scaling coefficients.

4 Layered Entropic Smoothing Operators

We introduce recursive field-deforming operators R_k across four cultural layers, each reducing cognitive entropy.

4.1 Layer 1: Language and Symbolic Recursion ($\mathcal{L}_1$)

Language acts as an entropy-reducing symbolic attractor set, with recursive reuse of compressed labels enabling efficient semantic traversal:

$$R_1(\Phi) = \Phi - \sum_i \chi(\ell_i), \tag{8}$$

$$R_1(\vec{v}) = \vec{v} + \sum_i \nabla\chi(\ell_i), \tag{9}$$

$$R_1(\mathcal{S}) = \mathcal{S} - \gamma_1 \sum_i |\nabla\chi(\ell_i)|^2, \tag{10}$$

where γ_1 controls the strength of entropy reduction.

4.2 Layer 2: Built Environment ($\mathcal{L}_2$)

The built environment compresses spatial affordances, simplifying perceptual search and action planning:

$$R_2(\vec{v}) = \vec{v} \odot \mathbf{A}, \tag{11}$$

$$R_2(\mathcal{S}) = \mathcal{S} - \gamma_2 \cdot \text{divergence suppression}, \tag{12}$$

where **A** is a structural affordance tensor, and γ_2 modulates spatial entropy reduction.

4.3 Layer 3: Social Norms and Institutional Roles ($\mathcal{L}_3$)

Social norms and roles reduce interpersonal entropy by providing distributed priors for agent prediction and alignment:

$$R_3(\Phi) = \Phi + V_{\text{norm}}(x, t), \tag{13}$$

$$R_3(\mathcal{S}) = \mathcal{S} - \gamma_3 \cdot \text{role consistency}, \tag{14}$$

where V_{norm} encodes normative potentials, and γ_3 reflects social coherence.

4.4 Layer 4: Technological Interfaces ($\mathcal{L}_4$)

Technological interfaces project high-dimensional action spaces into low-entropy semantic forms:

$$R_4(\Phi) = \Phi - \delta \cdot \text{GUI}_{\text{potential}}, \tag{15}$$

$$R_4(\vec{v}) = \pi(\vec{v}), \tag{16}$$

$$R_4(\mathcal{S}) = \mathcal{S} - \gamma_4 \cdot \text{control-efficiency}, \tag{17}$$

where π is a projection operator, and γ_4 quantifies interface efficiency.

5 The Entropy Smoothing Stack (ESS)

5.1 Hierarchical View

Each layer builds upon the previous, with intelligence emerging as cumulative entropy smoothing across the stacked recursion layers.

5.2 Formal ESS Model

The composite smoothing operator is defined as:

$$R_{\text{ESS}} = R_4 \circ R_3 \circ R_2 \circ R_1. \tag{18}$$

The intelligence functional under ESS is:

$$\mathcal{I}_{\text{ESS}} = \int_{\mathcal{M}} R_{\text{ESS}} \left(-\nabla \mathcal{S} + \lambda_1 \nabla \cdot \vec{v} + \lambda_2 \Delta \Phi \right). \tag{19}$$

6 Extensions and Applications

6.1 Neurocognitive Mapping

The RSVP framework maps to neural fields: Φ as error potentials, $\vec{v}$ as effective connectivity, and $\mathcal{S}$ as neural entropy. This enables experimental predictions for fMRI and EEG studies.

6.2 AI Alignment Interfaces

Interfaces can be designed to minimize $\mathcal{S}$ and maximize $\vec{v}$ alignment, enhancing interpretability through curvature-preserving compression.

6.3 Developmental and Evolutionary Implications

ESS layers evolve both phylogenetically and ontogenetically, suggesting intelligence as a product of deep-time entropic bootstrapping.

7 Conclusion

Intelligence is an emergent property arising from field-theoretic scaffolding across linguistic, architectural, social, and technological layers. Semantic recursion and structured environmental design deform the cognitive manifold to favor inference, compression, and coherence. The RSVP framework provides a unified, PDE-grounded model for these interactions, with broad implications for cognitive science and beyond.

A Definitions

- $\chi(\ell)$: Characteristic function encoding label-specific semantic compression.
- $\Theta(\ell)$: Context affordance spread, modulating label influence.
- π: Projection operator for technological interfaces.
- $\mathbf{A}$: Structural affordance tensor for the built environment.

B Sample Simulation Setup

A computational simulation of RSVP dynamics can be implemented using finite element methods to solve the PDEs, with initial conditions derived from empirical cognitive data.