

Amplitwist Cascades: Recursive Epistemic Geometry in Cultural-Semantic Evolution

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- **Challenge:** Modeling knowledge propagation across cognitive, social, and cultural scales is a complex interdisciplinary problem.
- **Solution:** The RSVP Amplitwist framework generalizes Needham's amplitwist to epistemic manifolds, capturing recursive semantic transformations.
- **Contributions:**
 - Recursive amplitwist operator $\mathcal{A}^{(k)}$ on semantic layers \mathfrak{R}_k .
 - Vorticity $\xi^{(N)}$ and efficiency $\eta^{(N)}$ metrics for epistemic dynamics.
 - Applications to linguistic evolution and AI alignment.
- **Talk Outline:** Historical context, mathematical framework, theorems, applications, computational simulation, and future directions.

- **Geometric Roots:** Builds on Thurston's foliations [?] and Needham's visual complex analysis [?].
- **Epistemic Geometry:** Models knowledge as flows on a manifold, extending geometric methods to cognitive and cultural systems.
- **Novel Concepts:**
 - *Cultural Curvature:* Torsion in $\Theta^{(N)}$ measures semantic divergence.
 - *Attractor Thermodynamics:* Entropy weights w_k control cognitive stability.
- **Interdisciplinary Relevance:** Connects differential geometry, cognitive science, and AI, addressing problems like semantic drift and model alignment.

Definition 2.1

Let M be a smooth n -dimensional manifold (epistemic space). Define:

- Scalar field $\Phi : M \rightarrow \mathbb{R}$ (semantic salience).
- Vector field $\vec{v} : M \rightarrow TM$ (conceptual velocity).
- Entropy field $\mathcal{S} : M \rightarrow \mathbb{R}^+$ (cognitive uncertainty).
- **Purpose:** Generalizes field theories to epistemic contexts, modeling knowledge dynamics as geometric flows.
- **Connection:** Aligns with cognitive theories (e.g., Hofstadter's analogy [?]) and geometric deep learning.

Definition

The RSVP Amplitwist $\mathcal{A} \in \mathbb{C}$ encodes local epistemic phase alignment:

$$\mathcal{A}(\vec{x}) = \|\vec{v}(\vec{x})\| \cdot \exp \left(i \cdot \arccos \left(\frac{\vec{v}(\vec{x}) \cdot \nabla \Phi(\vec{x})}{\|\vec{v}(\vec{x})\| \|\nabla \Phi(\vec{x})\| + \varepsilon} \right) \right),$$

where $\varepsilon > 0$ ensures numerical stability, and $\theta(\vec{x})$ is the phase angle.

- **Extension:** Generalizes Needham’s 2D amplitwist to n -dimensional manifolds.
- **Interpretation:** Captures magnitude and alignment of conceptual velocity with semantic gradients.

Definition 2.2

A semantic deformation layer \mathfrak{R}_k induces epistemic torsion:

$$\mathfrak{R}_k(\vec{x}) = \vec{x} + \sum_{j=1}^k \epsilon_j \mathbf{T}_j(\vec{x}), \quad \mathbf{T}_j \in \mathfrak{so}(n).$$

The layer- k amplitwist is:

$$\mathcal{A}^{(k)}(\vec{x}) = w_k(\vec{x}) \cdot \mathcal{A}(\mathfrak{R}_k(\vec{x})), \quad w_k(\vec{x}) = \exp(-\lambda \mathcal{S}(\vec{x})).$$

- **Mechanism:** Models hierarchical transformations (e.g., cognitive, social, cultural) via Lie group actions.
- **Significance:** Enables recursive analysis of knowledge propagation across scales.

Figure: Cascade of amplitwist fields across layers \mathfrak{A}_1 (primal cognition), \mathfrak{A}_2 (social interaction), \mathfrak{A}_3 (cultural scaffolding). Color gradients show $|\mathcal{A}^{(k)}|$.

- **Simulation Output:** Three-layer amplitwist magnitudes for $\Phi(x, y) = x^2 + y^2$, $\vec{v}(x, y) = (-y, x)$.
- **Insight:** Visualizes recursive epistemic transformations and attractor formation.

Theorem 3.1: Attractor Stability

For an N -layer system with $\epsilon_j < \epsilon_{\text{crit}}$, the vorticity $\xi^{(N)}$ converges:

$$\lim_{N \rightarrow \infty} \xi^{(N)} \leq \frac{C}{\text{Vol}(M)} \int_M \|\nabla \times \mathbf{T}_N(\vec{x})\| d\vec{x}.$$

Theorem 3.2: Efficiency Bound

The epistemic efficiency ratio $\eta^{(N)}$ satisfies:

$$\eta^{(N)} \geq \frac{\lambda_1(M)}{N \cdot \max_j \|\epsilon_j \mathbf{T}_j\|_\infty}.$$

- **Implications:** Ensure stability and quantify alignment costs in epistemic systems.

- **Model:** Linguistic change as a cascade of transformations:
 - \mathfrak{R}_1 : Phonetic drift (\mathbf{T}_1 = vowel shift).
 - \mathfrak{R}_2 : Grammaticalization (\mathbf{T}_2 = aspect-to-tense).
 - \mathfrak{R}_3 : Semantic bleaching (\mathbf{T}_3 = metaphor decay).
- **Visualization:**

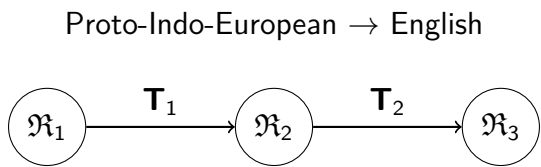


Figure: Linguistic evolution as a cascade.

Amplitwist Loss

For large language models (LLMs):

$$\mathcal{L}_{\mathcal{A}} = \sum_{k=1}^N \|\mathcal{A}_{\text{LLM}}^{(k)}(\vec{x}) - \mathcal{A}_{\text{human}}^{(k)}(\vec{x})\|^2.$$

- **Purpose:** Quantifies misalignment between machine and human epistemic dynamics.
- **Relevance:** Addresses AI safety and interpretability, e.g., semantic alignment in LLMs.