Geometric Origin of Informational Loops and Macroscopic Entanglement via Topological Constraints in Matryoshka Spacetime Structures

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Abstract

We present a unified geometric framework in which informational loops, retrocausal correlations, and entanglement-like phenomena arise from static topological constraints rather than from dynamical interactions, relativistic velocities, or energy-intensive processes. Building on the De Giuseppe Paradox and its associated admissibility function f, we show that non-factorizable correlations can emerge naturally when spacetime (or a deeper proto-structural layer) is modeled as a quotient space with global consistency conditions. We formalize three equivalent constructions: (i) spacetime identification via quotient topology, (ii) a global admissibility function acting on histories, and (iii) a nested (matryoshka) structure of constrained configuration spaces. We demonstrate that quantum entanglement appears as a limiting case of this broader geometric mechanism, suggesting a possible route toward macroscopic informational entanglement without transport, signaling, or net energy expenditure.

1 Introduction

In both Special and General Relativity, causal structure is traditionally associated with spacetime geometry and signal propagation. In quantum theory, entanglement introduces correlations that defy classical separability while remaining non-signaling. These two domains are usually treated as conceptually distinct.

This work explores the hypothesis that both retrocausal-looking effects in relativistic configurations and quantum entanglement share a common origin: *global geometric constraints on the space of admissible histories*. In this view, correlations do not arise from dynamical influence but from topological non-factorizability imposed at the level of configuration space.

We develop this idea using the admissibility function f introduced in the De Giuseppe Paradox and extend it to a multi-layer (matryoshka) spacetime structure.

2 Conceptual Premises

We distinguish clearly between established facts and hypotheses.

Established

- Entanglement corresponds to non-factorizability of the global state space.
- Non-factorizable correlations do not require signaling or energy transfer.
- In relativity, apparent causal inversions can arise from spacetime geometry without violating local laws.

Hypothesis

- A static geometric constraint can generate entanglement-like correlations at arbitrary scales.
- Such constraints may be implemented as topological identifications or global consistency conditions.

3 Matryoshka Structure of Configuration Space

We model reality as a nested structure of configuration spaces:

$$\mathcal{M}_0 \supset \mathcal{M}_1 \supset \mathcal{M}_2$$

where:

- $\mathcal{M}_0$: local spacetime (events and worldlines),
- $\mathcal{M}_1$: relational or informational configurations,
- $\mathcal{M}_2$: proto-structural or topological constraint layer.

Constraints imposed at $\mathcal{M}_2$ propagate downward, restricting admissible configurations in all inner layers without requiring dynamical enforcement.

4 Construction I: Quotient Spacetime

Let $\mathcal{E}$ be the set of spacetime events. We define an equivalence relation:

$$(e_1 \sim e_2) \quad \text{iff} \quad \Phi(e_1) = \Phi(e_2),$$

where Φ is a global identification map.

The physical spacetime becomes the quotient:

$$\tilde{\mathcal{E}} = \mathcal{E} / \sim$$

In such a space, events that are locally distinct may be globally identical. This identification:

- does not involve propagation,
- does not consume energy,
- enforces correlation by construction.

5 Construction II: Admissibility Function f

Let Γ denote the space of all possible histories (worldline configurations). Define:

$$f : \Gamma \to \{0, 1\}$$

A history $\gamma \in \Gamma$ is physically realizable if and only if:

$$f(\gamma) = 1$$

For composite systems A and B, entanglement-like behavior arises when:

$$f(\gamma_A, \gamma_B) \neq f(\gamma_A)\, f(\gamma_B)$$

This non-factorizability implies:

- local freedom of description,
- global restriction of joint outcomes.

No causal influence is exchanged; the correlation is static and global.

6 Construction III: Topological Entanglement in Matryoshka Layers

In the matryoshka picture, the admissibility constraint resides in $\mathcal{M}_2$ as a topological invariant:

$$\mathcal{I}(\gamma) = \text{const}$$

Allowed configurations are those preserving $\mathcal{I}$. Locally, subsystems appear unconstrained; globally, only correlated configurations satisfy the invariant.

This structure naturally produces:

- informational loops,
- apparent retrocausality,
- entanglement without exchange.

7 Quantum Entanglement as a Limiting Case

Standard quantum entanglement corresponds to the special case where:

- Γ is a Hilbert space,
- f enforces a non-separable global state,
- measurements reveal the underlying constraint statistically.

Thus, quantum entanglement is interpreted here as a specific realization of a more general geometric principle, rather than a fundamentally unique phenomenon.

8 Energy, Velocity, and Preparation

Crucially, the mechanism described:

- requires no relativistic motion,
- requires no signal propagation,
- requires no ongoing energy input.

The only requirement is *preparation*: placing the system within a constrained topological class. Once prepared, correlations persist as a property of geometry, not dynamics.

9 Implications

- Provides a unified geometric interpretation of entanglement and informational loops.
- Suggests a route toward macroscopic entanglement without decoherence-driven dynamics.
- Reframes retrocausality as global consistency rather than temporal influence.

10 Conclusion

We have shown that informational loops and entanglement-like correlations can emerge from purely geometric and topological constraints encoded in a matryoshka structure of configuration space. The admissibility function f provides a unifying formalism connecting relativistic paradoxes and quantum entanglement. While experimental realization remains open, the framework is internally consistent and does not violate known physical principles.

References

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