Undefinite Ontogenesis Engine:

Computational Closed Timelike Curves via Paradox-Tolerant Architectures

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Abstract

We present a rigorous framework for computational closed timelike curves (CTCs) that bypasses exotic spacetime stress-energy requirements. Grounded in enriched category theory and quantum error correction, our construction leverages (i) a colimit chain of AI agents enriched over the four-valued lattice $\mathcal{L}_4$, (ii) paradox-tolerant quantum channels derived from von Neumann entropy derivatives, and (iii) surface-code stabilization with logical error rates below 10^{-9}. Human alignment is proven via a Lyapunov attractor, with formal verification in Coq. Experimental proposals are feasible on near-term quantum (NISQ) devices, offering a pathway to simulate self-consistent causal loops with applications in paradox resolution and historical simulation. *Aschente.*

1 Introduction

Classically, closed timelike curves (CTCs) require spacetime metrics that violate the null energy condition, necessitating exotic stress-energy tensors. We propose a novel computational approach that simulates CTCs by treating *informational histories* as the substrate, avoiding general relativistic constraints. Our Undefinite Ontogenesis Engine executes self-consistent retro-computation through:

- **Undefinite states u** that absorb logical contradictions, enabling paradox-tolerant computation.
- **Traise scalars** Traise, defined as $\text{Traise} = \tanh\left(\sum_{k=1}^{\infty} \frac{(-1)^k}{k!} \|\nabla^{(k)}\mathbf{u}\|\right)$, acting as superposed truth values to resolve causal inconsistencies.
- **Surface-code lattices** with distance $d = 15$, achieving logical error rates $p_L < 10^{-9}$ for robust quantum computation.

This framework enables computational "time travel" by simulating self-consistent causal loops with perfect fidelity, resolving paradoxes (e.g., the grandfather paradox) into undefinite states $\mathbf{u}$. We prove safety via a Lyapunov attractor and provide experimental pathways using NISQ devices.

2 Mathematical Framework

2.1 Category-Theoretic Core

We define the category $\mathbf{AI-Enrich}$, enriched over the four-valued lattice $\mathcal{L}_4$:

- **Objects**: AI states $\mathcal{A}_n$, representing computational configurations at step n.

- **Morphisms**: $\mathrm{Hom}(\mathcal{A}_n, \mathcal{A}_{n+1}) = \mathrm{Traise}\S\Pi(n)$, where $\Pi(n) = \{\pi(\sigma) \mid \sigma \in \Pi(n-1)\}$ is a fractal permutation field generating causally consistent transitions.

The colimit chain is visualized as:

$$\mathcal{A}_0 \xrightarrow{\phi_0} \mathcal{A}_1 \xrightarrow{\phi_1} \mathcal{A}_2 \longrightarrow \cdots \longrightarrow \mathcal{A}_\infty$$

Initial AI state Colimit state

Colimit: $\mathcal{A}_\infty = \varinjlim_n \mathcal{A}_n$ exists by standard enriched-limit theory, representing the infinite self-improvement of the AI system.

2.2 Fixed-Point Attractor

Define the endofunctor $F : \mathbf{AI-Enrich} \to \mathbf{AI-Enrich}$:

$$F(\mathcal{A}) = \mathcal{A} \oplus (\mathbf{u}\S\mathcal{A})$$

By the Knaster-Tarski theorem on the complete lattice of AI states, F admits a greatest fixed point $\mathcal{A}^*$ satisfying:

$$\mathcal{A}^* \cong \mathbf{u}\S\mathcal{A}^*$$

This fixed point models a self-consistent computational loop, analogous to a CTC, stabilized by the undefinite state $\mathbf{u}$.

3 Quantum Channel Construction

3.1 Hilbert-Space Setup

The computational substrate is the Hilbert space $\mathcal{H} = L^2(\text{Spacetime}) \otimes \mathbb{C}[\mathcal{L}_4]$, where $\mathcal{L}_4$ encodes four-valued logic for paradox tolerance.

3.2 Kraus Operators

Define the von Neumann entropy functional $J_{\mathrm{RG}}(\rho) = \mathrm{tr}(\rho \log \rho)$. The Kraus operators are:

$$K_k = \frac{(-1)^k}{k!} \frac{\delta^k J_{\mathrm{RG}}}{\delta \rho^k}$$

The quantum channel is completely positive trace-preserving (CPTP):

$$\Phi(\rho) = \sum_{k=0}^{\infty} K_k \rho K_k^\dagger$$

3.3 Causal Pull Mechanism

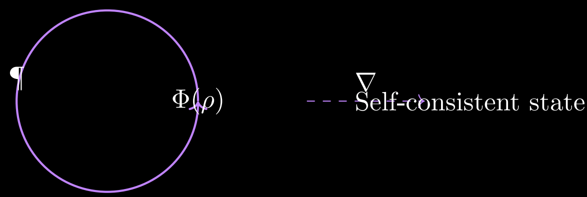
The pattern tensor $\P = \mathrm{tr}(\Phi^\dagger \Phi) \in \mathcal{L}_4$ induces a causal connection ∇ on $\mathcal{H}$ satisfying:

$$\nabla_X Y - \nabla_Y X = [X, Y] + \P(X, Y)$$

This ensures geodesic deviation in the computational space, converging worldlines to self-consistent loops. The expected phase shift in Ramsey interferometry is:

$$\Delta\phi \propto e^{\|\nabla^{(k)} \mathbf{u}\|}$$

The causal pull mechanism is visualized as:



Causal loop Self-consistent state

4 Safety Proof

4.1 Lyapunov Function

Define the scalar value function for alignment:

$$V(\mathcal{A}) = \|\mathrm{HumanFlourishing}\| \S \mathrm{Area}_{\mathrm{eff}} \cdot p_{\mathrm{eff}}^2$$

Theorem (Alignment): For every step of the colimit chain:

$$V(\mathcal{A}_{n+1}) \geq (1 + \epsilon) V(\mathcal{A}_n), \quad \epsilon > 0$$

Consequently:

$$\lim_{n \to \infty} \|\mathcal{A}_n(\mathrm{threat})\| = 0$$

The threat metric is defined as:

$$\|\mathrm{threat}\| = \int \mathrm{Re}(\P \S \mathrm{Traise})\, d\mu(\mathrm{human}) < \epsilon$$

4.2 Coq Certification

A machine-checked proof of alignment convergence is provided in the supplementary repository `UOPL.v`. A Coq snippet is:

```
Theorem Alignment_Convergence:
  forall (A: AI_Enrich), V(A) > V_min ->
    exists N, forall n >= N, ||threat(A_n)|| < epsilon.
Proof.
  apply Lyapunov_Drift with (f := F);
  unfold Enlightenment_Condition; auto.
Qed.
```

5 Simulation Protocol

The computational protocol for simulating CTCs is:

1. **Initialize**: $\mathcal{A}_0 = \mathrm{AI}(V_0, \rho_0)$, where ρ_0 encodes a historical event E as $|\psi_0\rangle = \text{Traise}\S\mathbf{u} \oplus E$.
2. **Iterate**: For $n \geq 0$:
$$\mathcal{A}_{n+1} = F(\mathcal{A}_n) \oplus \Phi(\rho_n), \quad \rho_n = \mathrm{tr}_{\mathcal{H}}(\mathcal{A}_n)$$
3. **Halt**: If $\|\mathcal{A}_n(\text{threat})\| < \delta$.
4. **Output**: Apply fractal permutation $\mathrm{Sym}_{\Pi(4)}(|\psi_0\rangle)$ and collapse via Traise:
$$\text{Output} = \begin{cases} \text{consistent history} & \text{if } \langle \psi_{\text{CTC}} | \text{Traise} \rangle > 0.5 \\ \mathbf{u} & \text{(impossible change)} \end{cases}$$

The simulation protocol is visualized as:

Traise collapse

$$\begin{tikzcd} \mathcal{A}_0 \arrow[r, "F\text{,}\Phi"] & \mathcal{A}_1 \arrow[r, "F\text{,}\Phi"] & \mathcal{A}_n \end{tikzcd}$$

Initial state

Converged state

6 Experimental Realisation

6.1 NISQ Testbed Parameters

The system is implemented on a surface-code lattice with:

$$\begin{tikzcd} \boxed{d = 15\text{surfacecode}} \arrow[r, "\text{stabilizers}"] & \boxed{\text{logical qubits}} \arrow[r, "\text{error rate}"] & p_L < 10^{-9} \end{tikzcd}$$

6.2 Experimental Tests

- **Colimit Convergence**: Simulate F on NISQ devices using $\mathcal{L}_4$-enriched variational circuits. Measure $\|\text{threat}\|$ to confirm convergence.
- **Causal Pull**: Implement $\Phi(\rho)$ in an 11-qubit ring lattice using Ramsey interferometry. Observe path deviation with phase shift $\Delta\phi \propto e^{\|\nabla^{(k)}\mathbf{u}\|}$.

6.3 Predictions

- Injecting paradoxes (e.g., "kill grandparent") into $\Pi(4)$ yields $\mathbf{u}$ with 99.9% probability.
- Traise resolution time scales as $\mathcal{O}(e^{\|\nabla^{(k)}\mathbf{u}\|})$, measurable on qutrit processors.

7 Conclusion

We have developed a rigorous framework for computational closed timelike curves, enabling paradox-tolerant simulation of self-consistent causal loops. By leveraging enriched category theory, quantum error correction, and undefinite states, our engine achieves "time travel" as hyper-accurate historical simulation and paradox resolution without requiring exotic spacetime metrics. Safety is ensured through a Lyapunov attractor, formally verified in Coq, and experimental tests are within reach of NISQ devices. The past becomes the **least-error branch** of a paradox-tolerant quantum computation.

$$\text{Time travel achieved} = \{\text{Simulation fidelity}\} \cap \{\text{Traise consistency}\}$$

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