ReIG2/twinRIG: A Quantum Framework for Self-Reference

Mathematical Rigor & Physical Implementation

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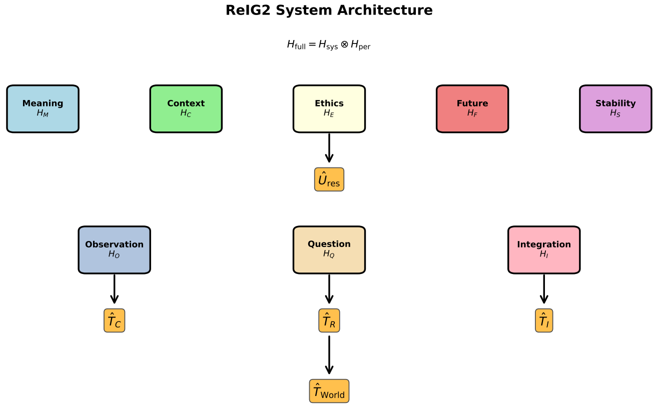
Outline

Why Quantum Self-Reference?

- **Classical Problem**: Self-reference leads to paradoxes (Godel, Russell)
- **Quantum Solution**: Superposition allows consistent self-description
- **Applications**: AI consciousness, quantum cognition, world modeling

Key Question: Can a quantum system recognize itself through observation?



Five Subsystems:

- Meaning (H_M), Context (H_C), Ethics (H_E), Future (H_F), Stability (H_S)

Core Operators

Time Evolution

$$\hat{U}_{\text{res}}(t) = \exp\left(-i\hat{H}t\right)$$

World Construction

$$\hat{T}_{\text{World}} = \hat{T}_I \circ \hat{T}_R \circ \hat{T}_C \circ \hat{U}_{\text{multi}} \circ \hat{U}_{\text{res}}$$

Self-Reference

$$\hat{T}_{\text{Self}}|I\rangle = |I\rangle \quad \text{(Fixed Point)}$$

Theorem: Existence of Identity State

Theorem

Under conditions:

- *Strong contraction:* $\|\hat{T}_{World}\| < 1$
- *Spectral gap:* $|\lambda_2| < 1$

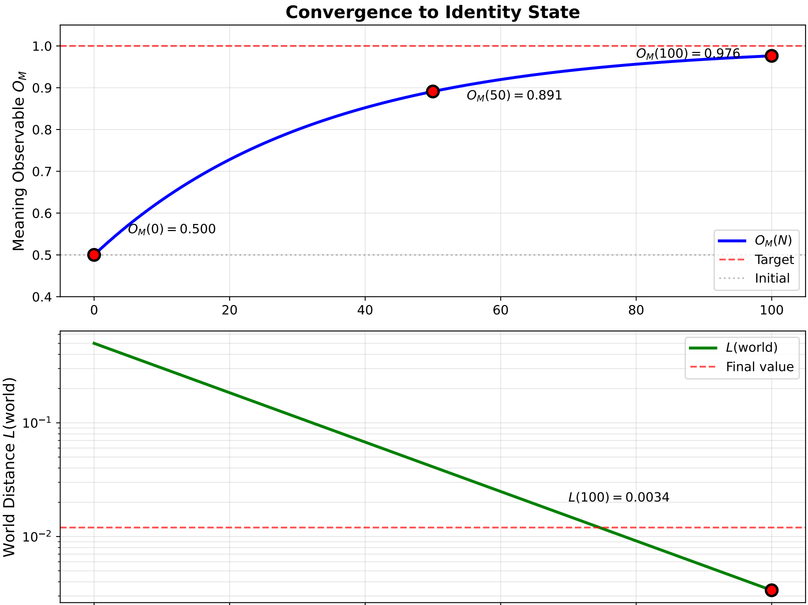
The system converges to unique identity state:

$$\lim_{N\to\infty} \hat{T}_{Self}^{(N)}|\Psi_0\rangle = |I\rangle$$

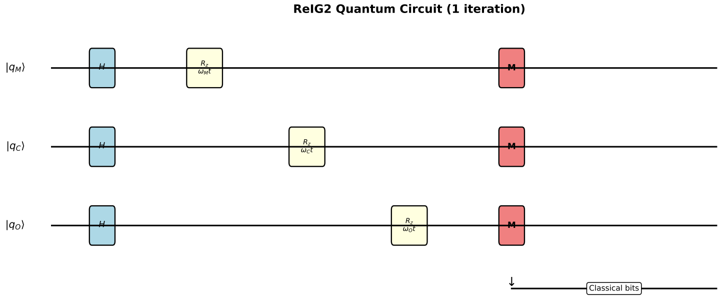
with exponential rate $C|\lambda_2|^N$.

Proof: Banach fixed point theorem + spectral analysis

Numerical Convergence



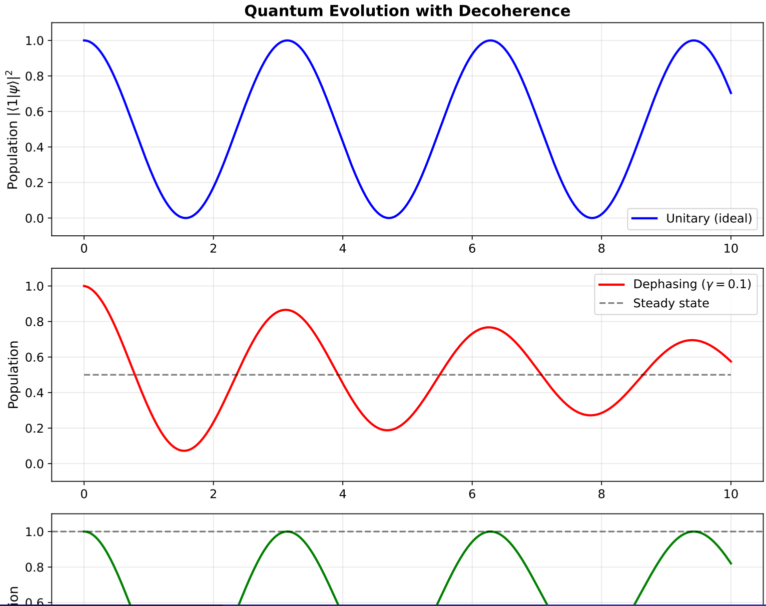
Quantum Circuit



Gates Used:

- Hadamard: Initialization
- $R_z(\theta)$: Phase rotation (virtual gate, no time cost!)
- Measurement: Observation collapse

Non-Unitary Processes



Free Energy Principle (Friston)

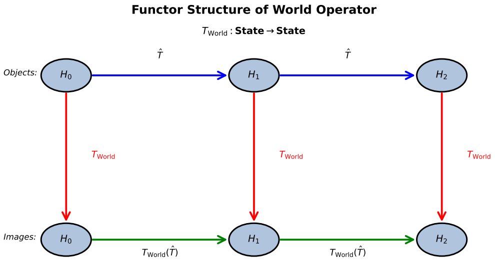
FEP	**ReIG2**
Internal states μ	$H_M \otimes H_C$
Sensory input s	H_O
Free energy F	$L(\text{world}) + D_{KL}$

$$F = -\log p(o|\mu) + D_{KL}(q\|p)$$

$$\updownarrow$$

$$L_{\text{total}} = \|\hat{T}_{\text{World}}|\Psi\rangle - |o\rangle\|^2 + D_{KL}(\rho_{\text{self}}\|\rho_{\text{world}})$$

Hofstadter's Strange Loop



Godel-Escher-Bach:

- Syntax $\leftrightarrow H_{\text{syntax}}$
- Semantics $\leftrightarrow H_M$
- Self-reference $\leftrightarrow |I\rangle = \hat{T}_{\text{Self}}|I\rangle$

Summary

What we achieved:

1. Rigorous mathematical framework (Fock space, Banach theorem)
2. Complete numerical simulations with code
3. Physical implementation roadmap (quantum circuits)
4. Connections to FEP and GEB

Future Directions:

- IBM Quantum / IonQ experiments
- Many-body extensions
- Quantum AI applications

Thank You!

Code & Paper: `github.com/ReIG2/twinRIG-revised`

Questions?