Meta-Quantum Computing on Calabi–Yau Manifolds CYbit and MetaCYbit

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Abstract

This paper introduces a novel computational paradigm based on Calabi–Yau (CY) manifolds. We present a progression from classical bits to quantum qubits, higher-dimensional qudits, and then to CYbits — quantum states defined on Calabi–Yau manifolds. Finally, we introduce Meta-CYbits, functionals acting on entire CY Hilbert spaces. We derive mathematical definitions, scaling estimates, and propose a roadmap for further exploration of this new model of computation.

1 Introduction

Classical computation is based on bits, taking discrete values 0 and 1. Quantum computation extends this to qubits, superpositions in a two-dimensional Hilbert space. Qudits generalize to dimension d, allowing states in $\mathbb{C}^d$. We propose to further extend this hierarchy by defining CYbits — states defined on Calabi–Yau manifolds — and Meta-CYbits, which operate at the level of functional spaces.

2 From Bits to Qubits

A classical bit:

$$b \in \{0, 1\}.$$

A quantum bit (qubit):

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \quad \alpha, \beta \in \mathbb{C},\ |\alpha|^2 + |\beta|^2 = 1.$$

3 Qudits

Generalization to dimension d:

$$|\psi\rangle = \sum_{i=0}^{d-1} \alpha_i |i\rangle, \quad \alpha_i \in \mathbb{C}, \quad \sum_{i=0}^{d-1} |\alpha_i|^2 = 1.$$

4 CYbits

Let M be a Calabi–Yau manifold of complex dimension k. Define a CYbit as:

$$\psi(x) \in L^2(M, \mathbb{C}^d).$$

Thus, information carriers are quantum states over CY geometry.

The Laplacian operator:

$$(Lf)(p_i) = \sum_{j:(i,j)\in E} w_{ij}(f(p_i) - f(p_j)),$$

encodes spectral and topological properties of M, with eigenvalues conjectured to reflect Hodge numbers $(h^{1,1}, h^{2,1})$ and Euler characteristic $\chi(M)$.

5 Meta-CYbits

We define Meta-CYbits as functionals over CY Hilbert spaces:

$$\Psi \in L^2(\mathcal{H}_{CY}, \mathcal{D}\psi),$$

where $\mathcal{H}_{CY}$ is the Hilbert space of CYbit states. These represent computations over spaces of quantum states themselves.

6 Scaling of Computational Capacity

For n information carriers:

- Classical bits: 2^n states.
- Qubits: 2^n-dimensional Hilbert space.
- Qudits (d-level): d^n states.
- CYbits (dimension m CY manifold, local d-level):

$$\sim (m^d)^n \quad \text{effective states.}$$

- Meta-CYbits: scaling extends to functional spaces, potentially beyond hyper-exponential growth.

7 Discussion and Research Directions

1. Spectral analysis: relation between Laplacian spectrum and CY topology.
2. Computational capacity: formulas linking capacity to Hodge numbers.
3. Error correction: construction of quantum codes from CY homology.
4. Dynamics: time as Ricci flow on CY metrics,

$$\frac{\partial g_{i\bar{j}}}{\partial \tau} = -\mathrm{Ric}(g)_{i\bar{j}}.$$

8 Conclusion

Meta-CY Quantum Computing offers a conceptual leap from qubits to manifold-based information carriers, and ultimately to functional-level Meta-CYbits. This framework opens a wide range of mathematical, physical, and computational problems.

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