Meta-Quantum Computing on Calabi–Yau Manifolds. Lecture. From Qudits to CYbits and Meta-CYbits

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Introduction

Good afternoon, colleagues. Today I will present a concept that extends the current understanding of quantum computing. We begin with the familiar — the bit and the qubit — and then move step by step towards a new computational unit: the *CYbit*, based on Calabi–Yau manifolds. We will then take another step and introduce the *Meta-CYbit* — an object that lives in the space of wave functionals. In this way, we obtain a system where quantum principles are "built into" the very structure of computation.

1 From Bit to Qubit

The classical bit is defined as

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

A qubit is described as a superposition:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \qquad |\alpha|^2 + |\beta|^2 = 1.$$

n qubits span a Hilbert space of dimension 2^n.

2 Qudits

The generalization of a qubit to d dimensions:

$$|\psi\rangle = \sum_{i=1}^{d} \alpha_i |i\rangle, \qquad \sum_{i=1}^{d} |\alpha_i|^2 = 1.$$

Qudits allow storing more information in a single cell and reduce the depth of quantum circuits.

3 CYbit

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

$$\psi : M \to \mathbb{C}^d, \quad \psi(p) = (\psi_1(p), \dots, \psi_d(p)).$$

The inner product:

$$\langle \psi, \phi \rangle = \int_M \psi^\dagger(p)\phi(p)\, d\mu(p).$$

Thus,

$$\mathcal{H}_{CY} = L^2(M, \mathbb{C}^d).$$

4 CYlink and CYgluon

The interaction between CYbits:

$$H = \sum_{(p,q)\in E} w_{pq} e^{i\phi_{pq}} U_{pq} \otimes |p\rangle\langle q| + \text{h.c.}$$

Parameters:

- w_{pq} — link weight (CY metric),
- ϕ_{pq} — phase (Berry integral),
- U_{pq} — transition operator.

We also introduce the *CYgluon* — an object describing link interactions:

$$\hat{\mathcal{G}}(L_1, L_2) \sim g \int \Psi[\psi]\, F[L_1, L_2; \psi]\, \mathcal{D}\psi.$$

5 Meta-CYbit

The key step is *second quantization*. A CYbit lives in $\mathcal{H}_{CY}$. Now we introduce a *wave functional*:

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

Normalization:

$$\int |\Psi[\psi]|^2\, \mathcal{D}\psi = 1.$$

The evolution is described by a functional Schrödinger equation:

$$i\hbar \frac{\partial}{\partial t} \Psi[\psi] = \hat{\mathcal{H}} \Psi[\psi].$$

6 Comparison of Levels

Level	Object	State Space
0	Bit	$\{0, 1\}$
1	Qubit/Qudit	$\mathbb{C}^d$
2	CYbit	$\mathcal{H}_{CY} = L^2(M, \mathbb{C}^d)$
3	Meta-CYbit	$\mathcal{H}_{Meta} = L^2(\mathcal{H}_{CY}, \mathcal{D}\psi)$

7 Computational Potential

Approximate estimates:

- Classical PC: 10^{12} operations/s.
- 50 qubits: $\approx 10^{15}$ amplitudes.
- 10 CYbits (3D, $m = 10$): $\approx 10^{30}$ amplitudes.
- 10 CYbits (6D, $m = 10$): $\approx 10^{60}$ amplitudes.
- Meta-CYbit: super-exponential functional space.

8 Implications

Mathematics: computational geometry of Calabi–Yau.
Physics: new applications of CY beyond cosmology.
Computer Science: a new paradigm of meta-quantum computing.
AI: potential new architectures for learning and modeling.

Conclusion

We have traced the path: bit $\to$ qubit $\to$ qudit $\to$ CYbit $\to$ Meta-CYbit. This hierarchy opens a new class of computational models, where quantum principles are embedded into the very structure of the architecture. Further research may lead to devices that operate in spaces we are only beginning to explore.

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