Research Roadmap for Meta-CY Quantum Computing

Evgeny Monakhov
LCC "VOSCOM ONLINE" Research Initiative
ORCID: 0009-0003-1773-5476

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Introduction

This roadmap outlines the development of the Meta-CY Quantum Computing framework, where information carriers are defined as quantum states on Calabi–Yau (CY) manifolds, and operations involve spectral, topological, and functional transformations.

1 Main Research Directions

1.1 CY-Time: Ricci Flow as Computation

- Model:
$$\frac{\partial g_{i\bar{j}}}{\partial \tau} = -\mathrm{Ric}(g)_{i\bar{j}}.$$
- Goal: describe time as projection of internal CY dynamics.
- Perspective: predictive models of evolution.

1.2 Error-Correcting Codes from CY Homology

- Code model:
$$[[n, k, d]], \quad d = \min\{\text{size of nontrivial cycle}\}.$$
- Goal: construct new families of robust quantum codes.
- Perspective: generalization of toric codes to higher-dimensional CYs.

1.3 Spectral Properties of CY Graphs

- Discrete Laplacian:
$$(Lf)(p_i) = \sum_{j:(i,j)\in E} w_{ij}(f(p_i) - f(p_j)).$$
- Hypothesis: spectrum encodes Hodge numbers $(h^{1,1}, h^{2,1})$ and Euler characteristic $\chi(M)$.
- Perspective: new link between spectral geometry and algebraic topology.

1.4 Computational Capacity of CY Manifolds

- Definition:
$$\mathcal{C}(M) = \log \dim_{\text{eff}}(\mathcal{H}_{CY}).$$
- Hypothesis:
$$\mathcal{C}(M) \sim f(h^{1,1}, h^{2,1}, \chi(M)).$$
- Perspective: quantitative theory of computational power of CYbits.

1.5 CYlinks and CYgluons

- CYlink:
$$H_{link}(i,j) = w_{ij}\, \psi^\dagger(p_i)\psi(p_j) + h.c.$$
- CYgluon:
$$H_{gluon}((i,j),(k,l)) = g_{ijkl}\, \psi^\dagger(p_i)\psi(p_j)\psi^\dagger(p_k)\psi(p_l).$$
- Perspective: novel architectures of computation with multi-level interactions.

1.6 Meta-CYbits as Functionals

- Definition:
$$\Psi \in L^2(\mathcal{H}_{CY}, \mathcal{D}\psi).$$
- Goal: describe computation at the level of spaces of states.
- Perspective: hypercomputation beyond BQP.

1.7 Mirror Symmetry as Computational Duality

- Goal: formalize mirror symmetry as transformation of computations.
- Perspective: dual algorithms and translation of problems across regimes.

1.8 Emergent Phases in CY Quantum Networks

- Goal: investigate collective behavior in CYbit networks.
- Perspective: emergence of computational phases (analogs of Bose condensation or superconductivity).

2 Conclusion

The proposed roadmap integrates mathematical and computational aspects. Its realization will provide a rigorous theory of Meta-CY Quantum Computing and uncover new architectures with unique stability and computational capacity.