Mesh Field Theory – Lecture 05:
Mesh Grover's Algorithm

From First Principles: Causal Amplification and Collapse

1. Introduction

Grover's algorithm is known for its quadratic speedup in unstructured search. In quantum theory, this is achieved through amplitude reflection and interference.

In Mesh, this behavior emerges from **field dynamics**: real phase inversion, coherence reflection, and energy concentration leading to collapse.

This lecture shows how Mesh reconstructs Grover's logic causally, using geometry and twist.

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2. Problem Statement

We are given N Mesh qubits $\{Q_1, Q_2, \ldots, Q_N\}$, each with identical coherence vectors:

$$\vec{C}(x_i, t_0) = \vec{C}_0 \quad \text{for all } i$$

One location x_* is the "marked" target.

The goal is to identify x_* using Mesh-native field dynamics — without measurement, without amplitudes, and without postulates.

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3. Mesh Oracle: Phase Inversion at Target

The Mesh oracle performs a local **phase inversion**:

$$\phi(x_*) \mapsto \phi(x_*) + \pi \quad \Rightarrow \quad \vec{C}(x_*) \mapsto -\vec{C}(x_*)$$

This flips the direction of coherence at x_*, creating destructive alignment relative to the others.

This inversion is physical: twist remains unchanged — only coherence direction flips.

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4. Mesh Diffusion: Reflection About Average Coherence

We compute the causal average:

$$\langle \vec{C} \rangle = \frac{1}{N} \sum_{i=1}^{N} \vec{C}(x_i, t)$$

Then apply field reflection:

$$\vec{C}(x_i, t) \mapsto 2\langle \vec{C} \rangle - \vec{C}(x_i, t)$$

This amplifies deviations — especially the inverted target — by realigning coherence toward the average field direction.

The field at x_* is now:
- **Constructively aligned** - **Doubled in magnitude** - **Closer to collapse threshold**

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5. Causal Iteration

Each Mesh Grover step consists of:

1. Phase inversion at target: $\vec{C}(x_*) \mapsto -\vec{C}(x_*)$
2. Field average: compute $\langle \vec{C} \rangle$
3. Reflect: $\vec{C}_i \mapsto 2\langle \vec{C} \rangle - \vec{C}_i$

After $O(\sqrt{N})$ iterations:
- Coherence energy at x_* grows significantly - Divergence threshold is reached:

$$\Gamma(x_*) > \Gamma_{\text{crit}}$$

- Collapse occurs **only at the target**

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6. Worked Example: $N = 4$

Initial coherence:

$$\vec{C}_i = (1, 0, 0) \quad \text{for all } i$$

Target: x_3
Apply Mesh oracle:

$$\vec{C}_3 = (-1, 0, 0)$$

Average:

$$\langle \vec{C} \rangle = \frac{(1 + 1 - 1 + 1)}{4} = \left(\frac{1}{2}, 0, 0 \right)$$

Reflection:

$$\vec{C}_3 \mapsto 2 \left(\frac{1}{2}, 0, 0 \right) - (-1, 0, 0) = (2, 0, 0) \quad \Rightarrow \quad \Gamma(x_3) \uparrow$$

After a few rounds, $\Gamma(x_3)$ exceeds threshold $\rightarrow$ collapse.

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7. Why This Works

Grover's speedup emerges in Mesh because:
- Target coherence becomes increasingly amplified - All others destructively self-cancel - Collapse is deterministic: the only location reaching threshold is the target

No probability. No observer. No Hilbert space.
Just causal buildup and collapse.

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8. Comparison to Standard Grover

— Feature — Quantum Grover — Mesh Grover — ——————————-————-— — Initialization — Uniform amplitudes — Uniform coherence vectors — — Oracle — Phase flip $|x_*\rangle \mapsto -|x_*\rangle$ — Phase inversion $\vec{C}(x_*) \mapsto -\vec{C}(x_*)$ — — Diffusion — Reflection about mean — Real coherence reflection — — Interference — Complex amplitude rotation — Causal vector amplification — — Measurement — Probabilistic collapse — Divergence-triggered deterministic collapse —
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9. Summary

Grover's logic emerges in Mesh as a physical effect:

- Oracle = field inversion - Diffusion = field average reflection - Amplification = real coherence buildup - Outcome = collapse at the most amplified region

This is not simulated logic. This is field-based search — causal, repeatable, and real.

Next: Phase estimation — and how frequency, not amplitude, carries truth.