Mesh Field Theory – Lecture 02:
Causal Operations and Coherence Interference

From First Principles: Information as Real Field Behavior

1. Introduction

In Mesh Field Theory, computation is not symbolic — it is physical.

Information is stored in real spatial coherence fields, and operations are performed by physically altering those fields. This lecture defines how Mesh qubits evolve, combine, interfere, and transform.

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2. Review: The Mesh Qubit

From Lecture 01, a Mesh qubit is defined as:

$$Q = (\phi(x,t),\ \chi(x,t),\ T(x))$$

Its coherence vector is:

$$\vec{C}(x,t) = \nabla\phi(x,t) \cdot \chi(x,t)$$

All computation begins and ends with this real vector — not complex amplitudes.

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3. Coherence Evolution (Natural Propagation)

Mesh qubits evolve by phase spreading through spacetime.

From the Mesh field equation:

$$\partial_t \vec{C} = -\nabla\left(\frac{1}{2}(\vec{C}\cdot\vec{C})\right) + (\text{external terms})$$

Interpretation:

- Coherence moves toward lower phase pressure. - This evolution is deterministic and local. - No unitary gate is needed — phase flows geometrically.

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4. Superposition: Field Addition

If two coherence regions overlap, their vectors sum:

$$\vec{C}_{\text{total}}(x,t) = \vec{C}_1(x,t) + \vec{C}_2(x,t)$$

This is not a quantum "superposition" of basis states — it is literal field interference.

Coherence either reinforces or cancels causally.

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5. Interference: Physical Overlap

Interference strength is measured by dot product:

$$\mathcal{I}_{12}(x,t) = \vec{C}_1(x,t) \cdot \vec{C}_2(x,t)$$

This tells us:

- $\mathcal{I} > 0$: constructive interference - $\mathcal{I} < 0$: destructive interference - $\mathcal{I} = 0$: orthogonal flow, no net interaction

This replaces $\langle \psi | \phi \rangle$ in Hilbert space — but with measurable vector geometry.

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6. Coherence-Based Logic: Native Mesh Operations

Operations in Mesh are not matrix multiplications. They are geometric reconfigurations.

6.1 Phase Shift Operation

To shift phase:

$$\phi(x,t) \mapsto \phi(x,t) + \delta \quad \Rightarrow \quad \vec{C}(x,t) \mapsto \vec{C}(x,t)$$

(no change in direction, only in propagation timing)

6.2 Coherence Flip (X-Equivalent)

Flip the direction of phase gradient:

$$\vec{C}(x,t) \mapsto -\vec{C}(x,t) \quad \text{(field inversion)}$$

This inverts phase flow — analogous to a bit-flip.

6.3 Twist Toggle

Apply or remove twist channel:

$$T(x) \mapsto T'(x), \quad T' \in \{[1,0,0], [0,0,0], \dots\}$$

This toggles the charge structure of the Mesh qubit — a core operation.

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7. Entanglement (Causal Overlap)

Two Mesh qubits are entangled if:

- Their causal cones overlap, and - Their coherence vectors become phase-aligned:

$$\vec{C}_A(x,t) \cdot \vec{C}_B(x,t) > 0 \quad \text{for } x \in \text{overlap region}$$

They do not "share a wavefunction" — they **share real causal structure**.

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8. Collapse Reminder

If coherence builds too strongly in one location:

$$\Gamma(x,t) = \nabla \cdot \vec{C}(x,t) > \Gamma_{\text{crit}}$$

The Mesh qubit **collapses** — not by measurement, but by structural breakdown.
The result is deterministic, but initial coherence configuration controls the outcome.
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9. Summary

A Mesh qubit is not operated on by symbolic gates. It is shaped and transformed by:
- Phase shifts - Twist application or removal - Directional field reconfiguration - Physical overlap and divergence

These define **Mesh-native logic**.
This is not metaphor. This is **causal field computing**.
Next lecture: twist-state transitions, field scattering, and computational flow.

10. Worked Example: Constructive and Destructive Mesh Interference

To match the style of CMU's Lecture 02, we now provide a detailed Mesh-native version of a simple interference scenario.

10.1 Setup: Two Mesh Qubits with Opposite Coherence

Prepare two Mesh qubits located at the same spatial region:

$$\vec{C}_1(x,t) = (1,0,0) \quad \text{and} \quad \vec{C}_2(x,t) = (-1,0,0)$$

These fields are equal in magnitude but point in opposite directions.

10.2 Total Field and Interference

Add the fields:

$$\vec{C}_{\text{total}}(x,t) = \vec{C}_1 + \vec{C}_2 = (0,0,0)$$

Compute the dot product:

$$\vec{C}_1 \cdot \vec{C}_2 = -1 \quad \Rightarrow \text{destructive interference}$$

This means:
- Coherence is canceled, - No divergence will occur, - Collapse is suppressed.

10.3 Modified Setup: Aligned Coherence

Now let:

$$\vec{C}_1(x,t) = (1,0,0) \quad \text{and} \quad \vec{C}_2(x,t) = (1,0,0)$$

Then:

$$\vec{C}_{\text{total}} = (2,0,0) \quad \text{and} \quad \vec{C}_1 \cdot \vec{C}_2 = 1 \quad \Rightarrow \text{constructive interference}$$

- Coherence is reinforced, - Divergence increases, - Collapse is more likely if $\Gamma > \Gamma_{\text{crit}}$

10.4 Conclusion

Mesh interference is not about amplitude cancellation — it is about **real vector direction and coherence flow**.

Constructive interference causes **energy buildup and potential collapse**. Destructive interference causes **energy cancellation and persistence**.

This directly mirrors the role of amplitude-based interference in quantum computing — but with causal structure and physical observability.