Quantum Simulation of Battlefield Scenarios
Indra Challenge

QUBITO TEAM

1. Problem & Idea

Quantum vs Classical Battlefield Movement

- We control a set of **soldiers on a battlefield**
- Each soldier must move to an **optimal nearby position**
- Around each soldier there are **9 possible positions** *(stay, or move to one of the 8 neighboring cells)*

Challenge

- Moves must be **consistent** (no contradictory orders)
- Soldier movements should be **coordinated**, not independent

Classical vs Quantum

- **Classical**: Classical Random Walk
- **Quantum**: explore *all moves simultaneously* and let physics select the best coordinated outcome

Goal: encode battlefield movement as a quantum system whose **lowest-energy state gives the optimal repositioning**

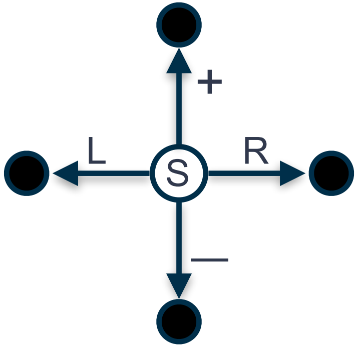
1. Quantum Encoding of Movements

Quantum Decision with Hard Constraints

Setup

Four binary actions are mapped to four qubits:

$$\{R, L, +, -\}$$



Each qubit encodes an action in each direction:

$$|0\rangle = \text{Stay}, \qquad |1\rangle = \text{Move}$$

Constraints

We cannot have contradictory movements:

$$(R, L) = (1,1) \text{ and } (+, -) = (1,1) \text{ are forbidden}$$

Core Idea : We extend this encoding to each soldier on the battlefield. The decision problem is mapped to a Hamiltonian H, whose ground state represents a valid, correlated set of actions, thereby maximizing coordinated collective movement.

2. Hamiltonian Design.

The decision problem is encoded into a Hamiltonian

$$H = H_Z + H_{XX} + H_{\textbf{penalty}} \cdot$$

1) Local preferences:

$$H_Z = \sum_{a \in \{I, D, +, -\}} h_a Z_a, \quad h_a = O_a - V_a \, .$$

The coefficients h_a represent the effective interaction of each possible movement with the surrounding enemy environment (local cost or benefit of taking action a).

2) Correlations:

$$H_{XX} = \sum_{a<b} J_{ab} X_a X_b, \quad J_{ab} = O_{ab} - V_{ab} \, .$$

The couplings J_{ab} encode correlations between actions, modeling how pairs of movements jointly interact with the battlefield and nearby enemies. These terms generate entanglement and prevent trivial classical solutions.

3) Hard Constrains:

$$H_{\textbf{penalty}} = K_{ID} |11\rangle\langle 11|_{ID} + K_{+-} |11\rangle\langle 11|_{+-} \, .$$

The penalty strengths $K_{ID}, K_{+-} \gg 1$ assign a large energy cost to forbidden configurations, ensuring that contradictory movements (left & right or up & down) never appear in the ground state.

3. From Quantum State to Action.

The quantum system naturally settles into its **lowest-energy configuration**, which corresponds to the **best combination of movement choices**.

Each qubit represents one possible action, so the final quantum state encodes which actions should be taken together.

This combination of actions can be read as a **bitstring**, where each bit indicates whether a specific movement (left, right, up, or down) is chosen.

Because only one classical action can be taken, the system is measured repeatedly, and the **most frequently observed bitstring** is selected as the final decision.

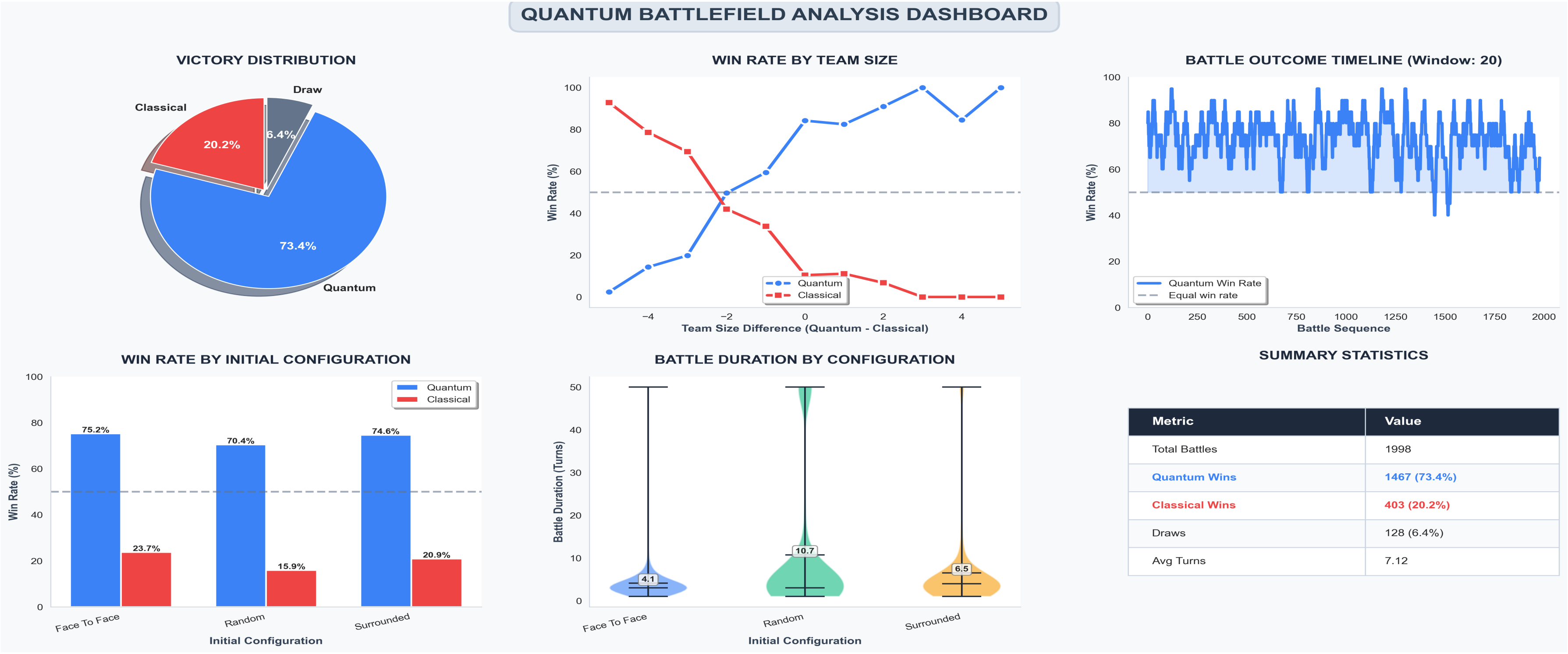
The selected bitstring determines the movement explicitly for each particle:

$$\begin{aligned} L &= 1 \Rightarrow \text{ move left}, & R &= 1 \;\Rightarrow\; \text{move right}, \\ + &= 1 \Rightarrow \text{ move up}, & - &= 1 \;\Rightarrow\; \text{move down}\,. \end{aligned}$$

Hard constraints ensure that opposite directions are never chosen simultaneously.

4. Numerical Experiments.

We construct a four-qubit decision Hamiltonian for one soldier and compute its ground state.
The most probable measured bitstring determines the soldier’s movement.



Metric	Value
Total Battles	1998
Quantum Wins	1467 (73.4%)
Classical Wins	403 (20.2%)
Draws	128 (6.4%)
Avg Turns	7.12