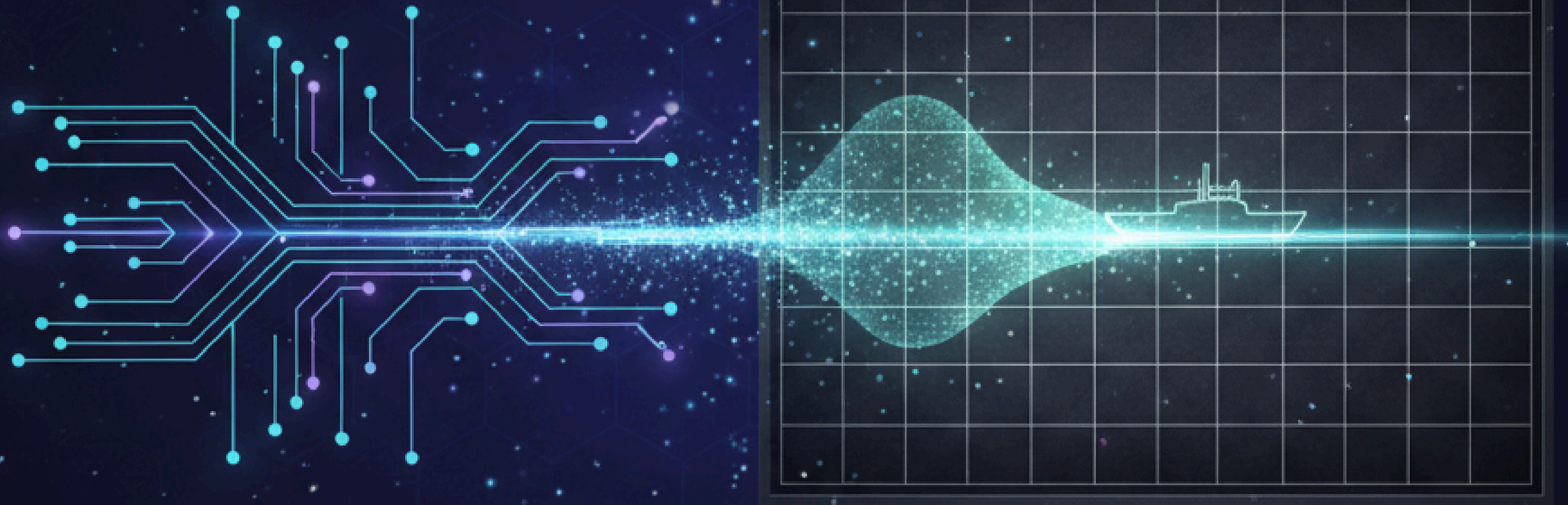


Quantum Radar: Interaction-Free Measurement for Battleship



The Challenge: Quantum Battleship

- Reinventing Battleship using quantum mechanics
- Detect ships across rows/columns without direct hits

The Goal: Maximize E.V. Score

- Elitzur-Vaidman (E.V.) Score:
$$\frac{\text{Successful Detections}}{\text{Total Ship Hits}}$$
- Aim for a perfect score: all detections, zero hits

Our Core Approach: Interaction-Free Measurement (IFM)

- Leveraging the "bomb tester" concept
- Detecting presence by observing what doesn't happen

Our Algorithm: The Quantum Zeno Effect (QZE)

- We implemented an advanced "bomb tester" using the Quantum Zeno Effect.
- The Idea: A quantum system's evolution (like a qubit rotating from $|0\rangle$ to $|1\rangle$) can be "frozen" by rapid, repeated interactions.

The Zeno Circuit (Run N=15 times in one circuit)

- Small Rotation: Apply a tiny Ry rotation to a "probe" qubit (moving it slightly from $|0\rangle$ towards $|1\rangle$).
- Oracle Check: Use an oracle (MCX gate) to check if any square in the row/column contains a ship.
- Interaction: A CZ gate "nudges" the probe qubit only if the oracle found a ship.
- Uncompute: Reverse the oracle to reset the state qubits, leaving them undisturbed.

How We Read the Results

- We only measure the probe qubit at the very end.
- "MISS" (No Ship): The probe rotated freely for 15 steps and is now measured as $|1\rangle$.
- "DETECT" (Ship Present): The 15 interactions "froze" the probe's rotation. It is still measured as $|0\rangle$.

Our Game Strategy (3-Stage Process)

- We implemented the 2-stage scan suggested by the prompt to efficiently find the ship.

Stage 1: Full Row Scan

- Run the Zeno circuit on each of the 4 rows.
- We check which rows return "DETECT" (i.e., probe measured as $|0\rangle$ ~100% of the time).
- Result: Correctly identified Row 1 as the only row of interest.

Stage 2: Targeted Column Scan

- For Row 1, we run the Zeno circuit on each of the 4 columns.
- Result: Correctly identified Col 0 and Col 1 as "DETECT".

Stage 3: Ship Inference

- Our algorithm combines these results to pinpoint the ship's location.
- Final Inferred Position: Row 1, Columns 0-1.

Final Results: A Perfect Score

- Our Quantum Zeno algorithm's performance on the 4x4 board:
- Successful Detections: 3
- Total Ship Hits: 0
- Total Misses: 5

Official E.V. Score: $3/0=\infty$ (Perfect Performance)

- This infinite score signifies the ideal outcome: we found the ship's location without ever causing a destructive "hit."

Comparison: Baseline (Destructive) Circuit

- A standard H-CX-H circuit resulted in 765 hits for 424 detections.
- Baseline E.V. Score: 0.5542

Conclusion

- Our QZE algorithm demonstrates a flawless "Interaction-Free Measurement," achieving the core objective of the challenge.