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2nd Year
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QuBS - Quantum BattleShips

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Overview

Quantum Battleships is a modified adaptation of the Elitzur-Vaidman “quantum bomb” thought experiment into a game-like framework inspired by Battleship. The goal is to detect the position of hidden ships on a N x N grid with minimum chance of hitting them.

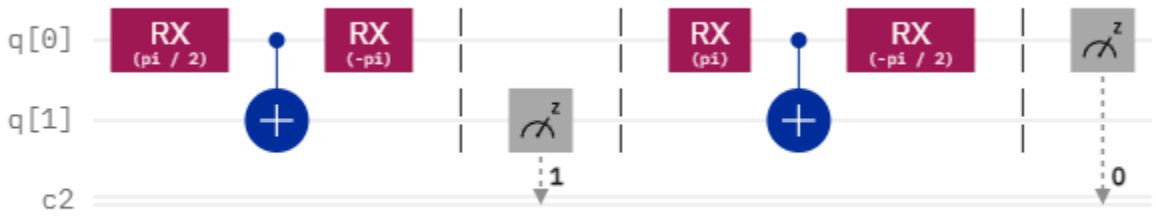
Instead of firing classical probes at every cell (which would hit the ship), we use quantum superposition and entanglement inspired from the MZI experiment (Mach-Zehnder Interferometer) to probe multiple cells simultaneously and extract information without attacking the ships.

Goals

1. **Minimum required measurements:** One of the goals of QuBS is to minimize the total number of measurements required in the quantum approach.
2. **Maximize E.V. score:** E.V. score is calculated as the probability of detection / probability of explosion (in this case, hitting any part of the ship). QuBS aims to find a perfect spot through graphical analysis of different plots for the rotational parameters of the Rx gate.

Methodology & Reasoning

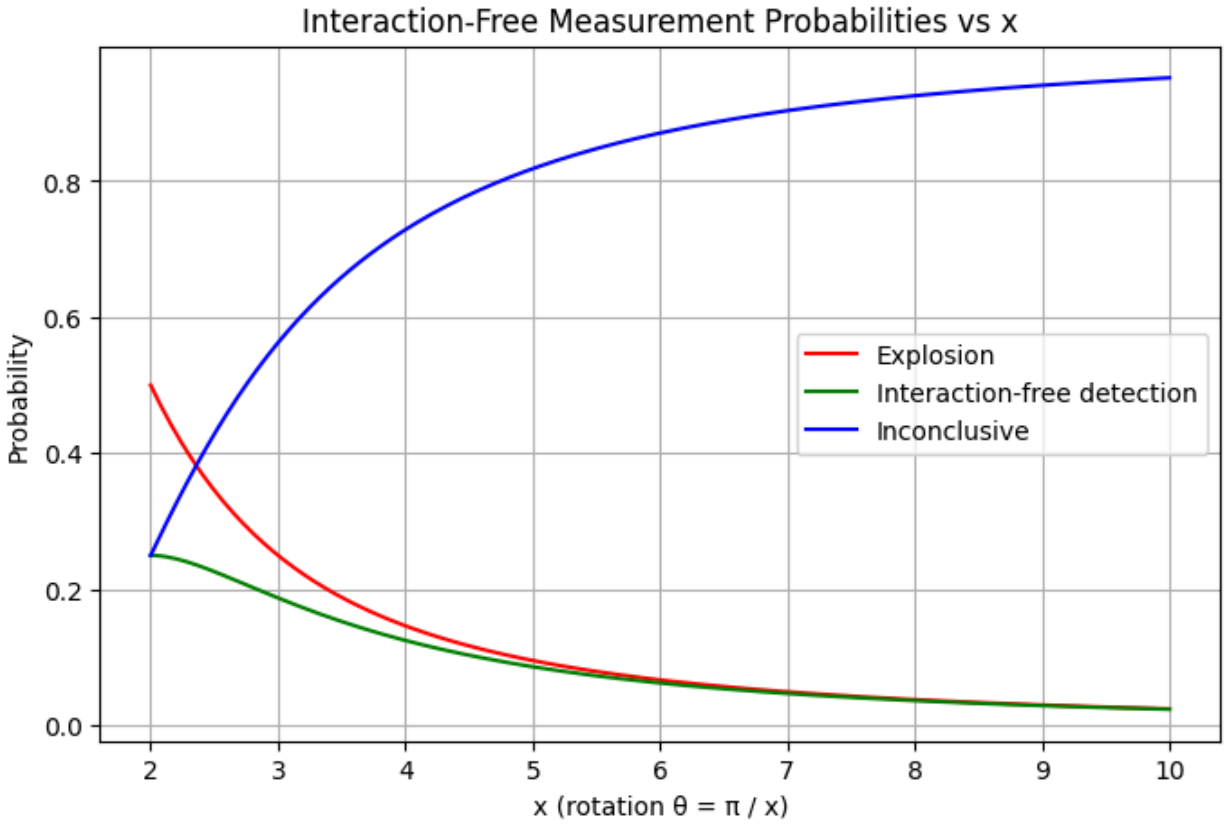
1. First, to understand how the MZI experiment worked with different parameters and how the resulting probabilities map to the solution, I tried to recreate the circuit on the IBM Composer.



Computational basis state	Probability
00	23.33984%
01	27.14844%
10	24.80469%
11	24.70703%

Here the states are represented in the default Qiskit representation (with the MSB (q1) on the leftmost position). We can infer from this that if the MSB is 1, the bomb has exploded. 00 gives us inconclusive results, and 01 is our detection probability. Here, the E.V. score is approximately 50%.

2. Experimenting with the RX rotation gate parameters, one can infer that a smaller value leads to different results. I made a graph by parametrizing the rotation gates to the value $z = \pi/x$.



To maximize the E.V. score, we need the detection / explosion ratio to be as high as possible. However, the higher the score, the higher the chance of non-conclusivity of our result. So we take the value where the explosion probability is lower than the inconclusive result (the quantum Zeno transition).

Point where Explosion = Inconclusive:

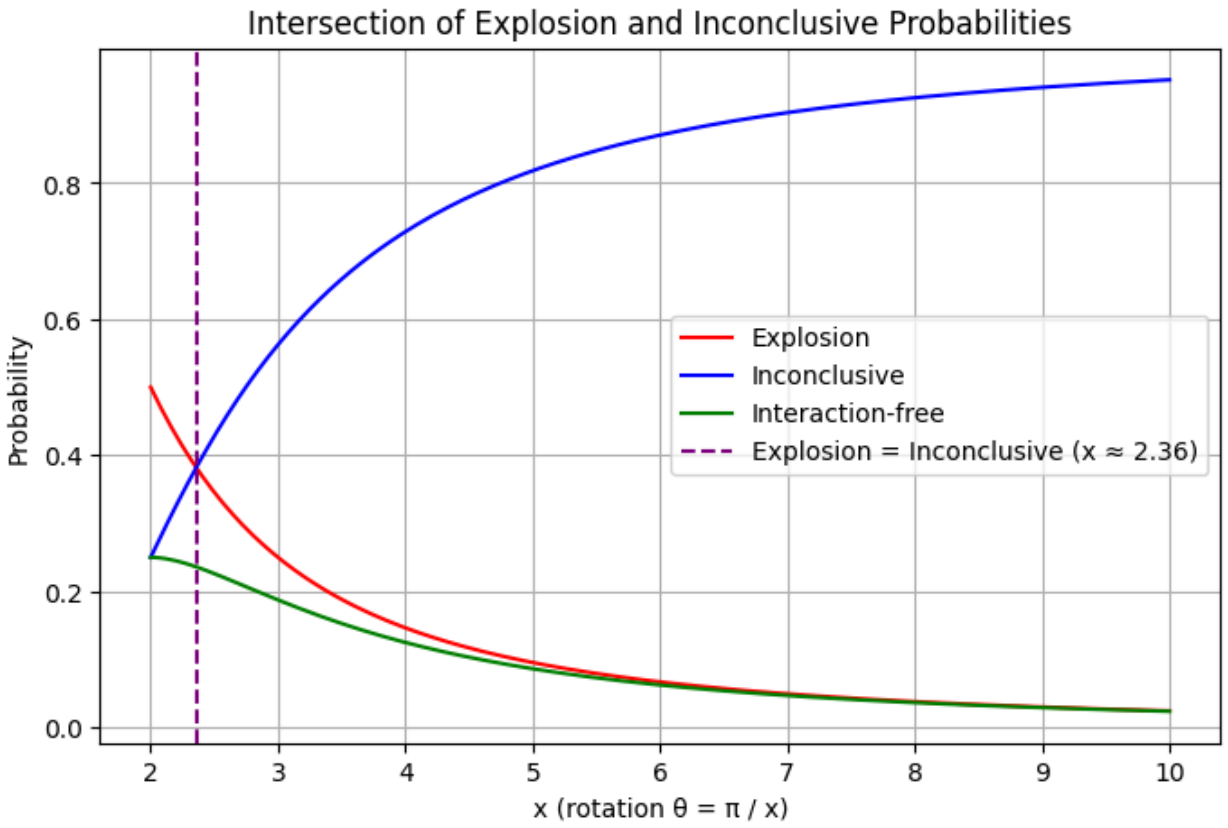
$x \approx 2.362$

$\theta = \pi / x \approx 1.330$ radians

Explosion = 38.084%

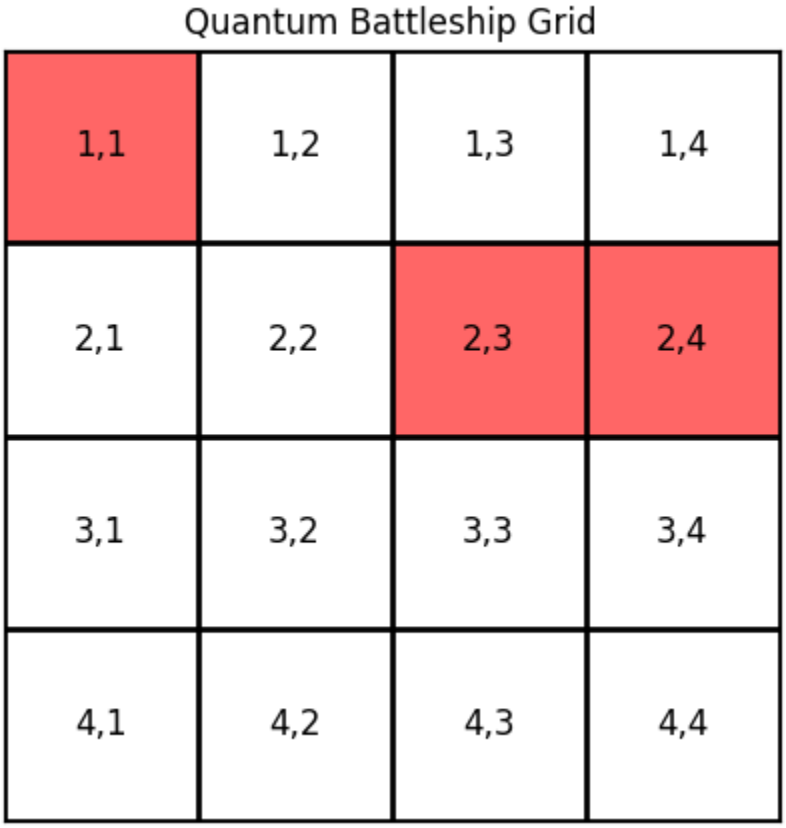
Inconclusive = 38.336%

Interaction-free = 23.580%

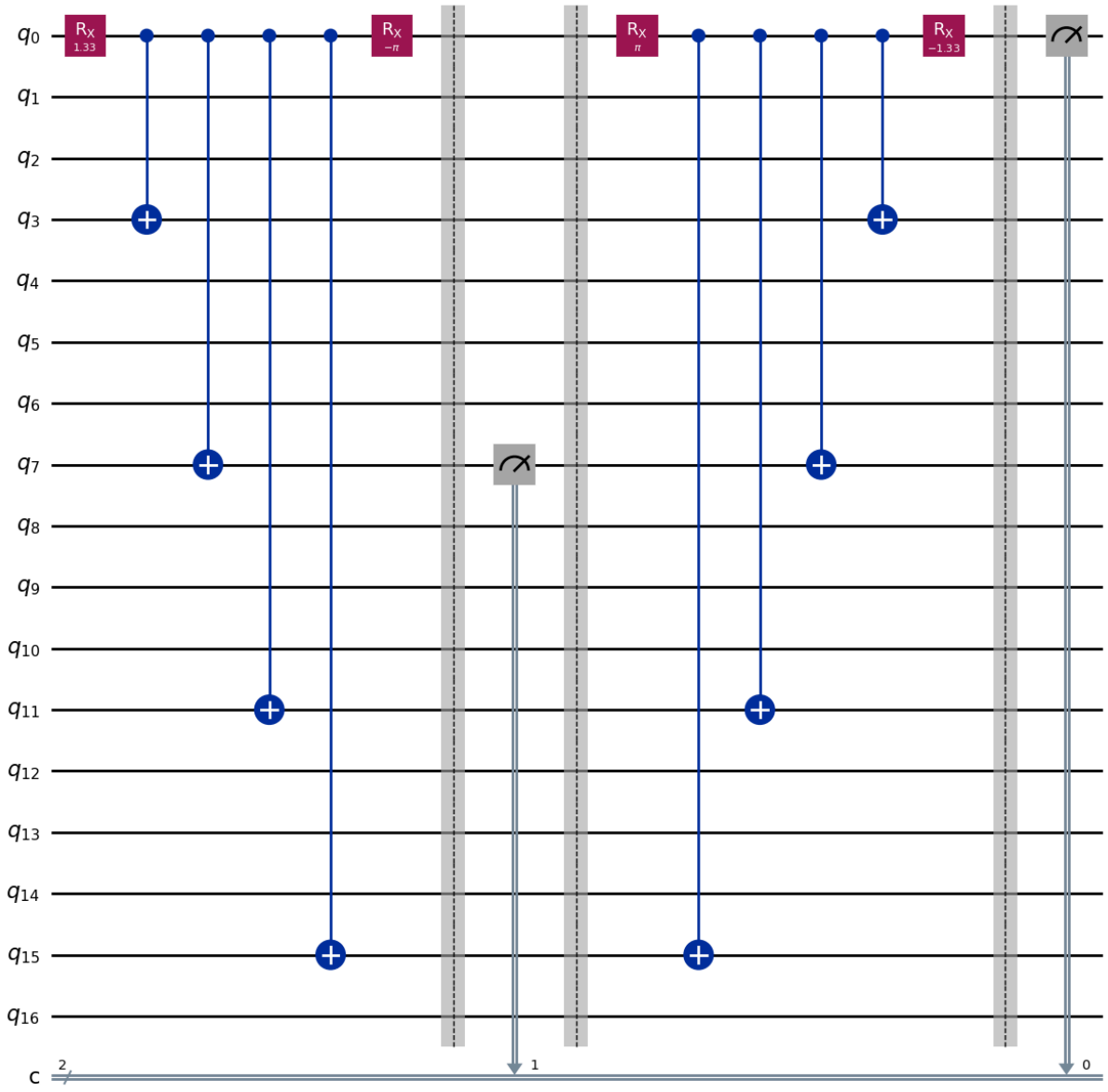


This gives us our E.V. score to be approximately **61.50** with results being 38.336% inconclusive (which translates to approx. 61.664% accuracy per measure)
With the foundations established we can continue our battleship experiment.

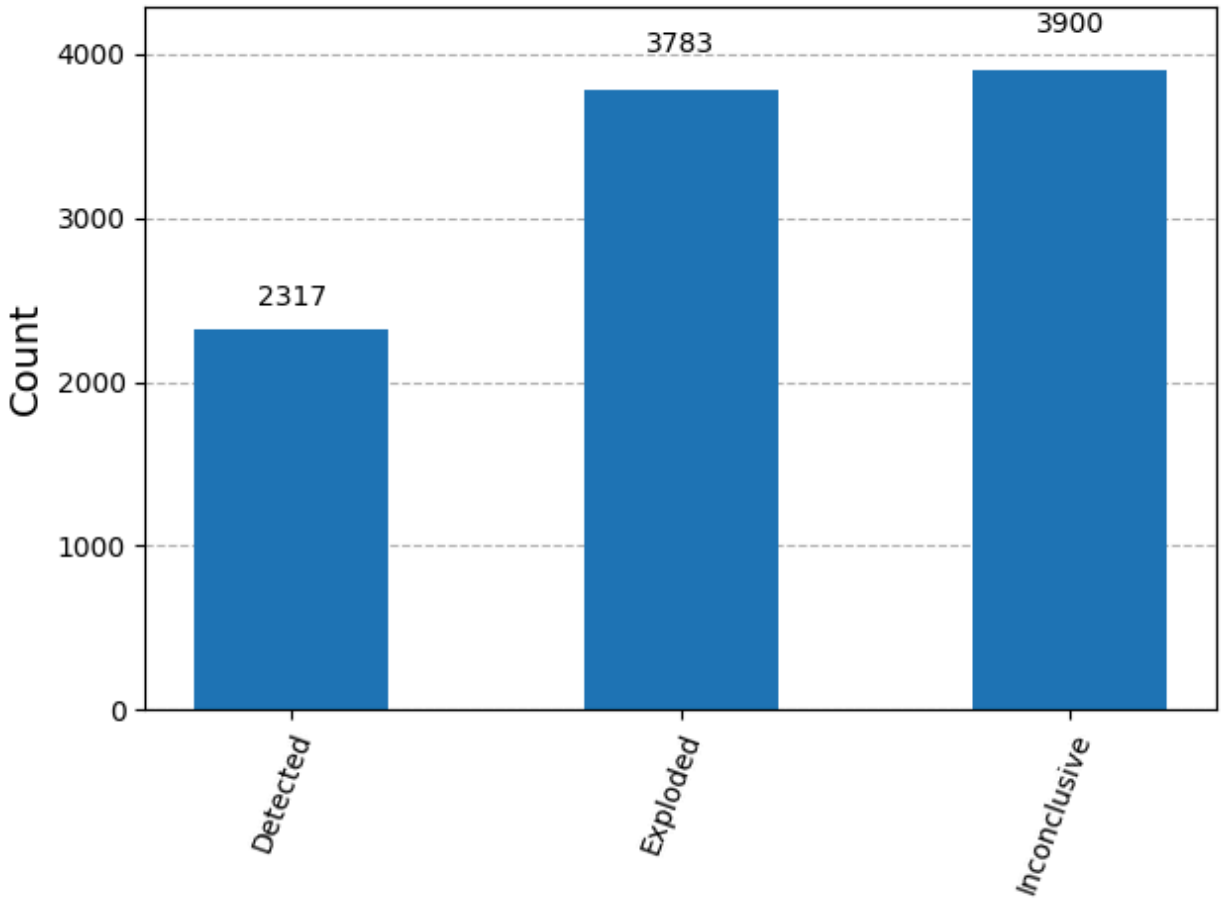
3. After this I built the code for a battleship black box with the above values in mind, all the code cells are annotated and arranged in the QuBS.ipynb file. Some of the results I achieved are mentioned here:



The red cells denote the boats.



This is the circuit for the column 3 probe in the above example.



The above histogram links to a single column probe contained one boat cell (column 3).

Final results:

Filtered EV scores: {'row_1': 0.6022845275181724, 'row_2': 0.6453691275167786, 'col_1': 0.6174183514774495, 'col_3': 0.6216993464052287, 'col_4': 0.6155253528489284}

Highest EV score: 0.6454 (row_2)

Battleship score factor: 0.5000

Final quantum battleship score: 0.3227

Challenges

1. E.V. Score

   The E.V. score can go to 1 on a 100% inconclusion data measure. This can be avoided by using a parameter where we get equivalently non-conclusive or explosive measure.

2. Inference of boat cells from the black box

   Since we are only doing row/column measurements, we cannot accurately determine the exact cells containing the boats, but an intersection of the EV rows and columns will give us a general estimate (according to the battleship score) regarding our chance of inferring a correct boat location.