Elitzur-Vaidman wins Battleship without firing a single shot
– NOTE: this is not the quantum battleship of the medium paper!

Background and Motivation

The 1990s marked a pivotal era for quantum computing. In 1994, Peter Shor published the algorithm carrying his name [1], demonstrating how quantum mechanics could offer a computational advantage. Just a year later, in 1995, David Wineland's team achieved a monumental feat by implementing the first quantum logic gate using trapped ions [2], a cornerstone of quantum computing. The innovations continued, and in 1997, Anton Zeilinger's team published the first experimental demonstration of quantum teleportation [3].

Amidst these advancements, 1993 saw Avshalom Elitzur and Lev Vaidman propose a thought-provoking Bomb Tester experiment designed to explore core fundamental quantum mechanics concepts: entanglement, superposition, and state collapse [4]. Their dramatic bomb tester thought experiment involved using a Mach-Zehnder interferometer to detect the presence of a bomb without detonating it. This was a revolutionary concept: the ability to gain information about an object without any direct interaction.

This hackathon challenges you to build upon the Elitzur-Vaidman Bomb Tester. Your mission is to extend this non-interactive probing method to a Battleship game grid, aiming to locate all ships without "hitting" them. In traditional Battleship, finding a ship means a direct hit or miss. However, the Elitzur-Vaidman Bomb Tester showcases the power of quantum mechanics to probe objects without interaction. In this hackaton you will develop a quantum circuit that leverages core quantum concepts to find every ship on the Battleship grid and secure victory before firing a single shot.

Getting Started

This hackathon challenge is divided in three parts:

1. Learn how to translate the original Elitzur-Vaidman Bomb Tester into a quantum circuit.
2. Learn how to upgrade the original Elitzur-Vaidman Bomb Tester to get close to a 100% detection of bombs (the opponent ships) without interacting with them. This can make use of dynamic circuits and/or better Elitzur-Vaidman design through repetition [5].
3. The real challenge: Apply these concepts to the analogous Battleship game, in this case we provide a random Battleship grid [an operator acting over ~16 qubits] (which is hidden to the user), and you will need to detect the ship locations without interacting with them.

The output circuit will be evaluated with a grader function over some different random Battleship scenarios and rank how many ships are detected.

Suggested Resources

[1] Shor, P. W. (1994). Algorithms for quantum computation: discrete logarithms and factoring. In *Proceedings 35th annual symposium on foundations of computer science* (pp. 124-134). IEEE.

[2] Monroe, C., Meekhof, D. M., King, B. E., Itano, W. M., & Wineland, D. J. (1995). *Demonstration of a fundamental quantum logic gate*. Physical Review Letters, 75(25), 4714-4717.

[3] Bouwmeester, D., Pan, J. W., Mattle, K., Eibl, M., Weinfurter, H., & Zeilinger, A. (1997). Experimental quantum teleportation. Nature, 390(6660), 575-579.

[4] Elitzur, A. C., & Vaidman, L. (1993). Quantum mechanical interaction-free measurements. Foundations of Physics, 23(7), 987-997.

[5] Pereira Pinto, V., Pereira de Oliveira, B., Mitsue Yasuoka, F. M., Courteille, P. W., & Caiado de Castro Neto, J. (2023). Exploring Quantum Comprehension Through the Elitzur-Vaidman Bomb Testing Problem. *Brazilian Journal of Physics*, *53*(6), 152.

General Elitzur-Vaidmand description from Wikipedia: https://en.wikipedia.org/wiki/Elitzur%E2%80%93Vaidman_bomb_tester

Pennylane exercise demonstrating use of dynamical circuits: https://pennylane.ai/codebook/pennylane-fundamentals/dynamic-circuits

Blog demosntraing extension to multiple bombs: https://algassert.com/post/1700