Quantum Connect Four

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1 Introduction

Our game is Quantum Connect Four, a multiplayer game based on the classical version of Connect Four. The game consists of a 4x4 array of cells that each player can fill with classical bits or qubits.

To play, the first player should choose which mode they want to play in. For example, if the player wishes to superpose a pair of cells, they should select two cells. The classical mode is on by default.

The players take turns placing different colored pieces into the board until they can form a horizontal, vertical or diagonal line of 4 pieces. In addition to placing classical ('solid') pieces, players can also form quantum superpositions ("light" pieces) by clicking the 'Add Qubit' button and placing two quantum pieces in different spots, such that the piece has a different chance of appearing in either spot upon quantum measurement. Forming superpositions with quantum pieces serves the additional purpose of denying crucial squares to opponents. At any point, players have the option to measure a qubit and collapse its superposition, allowing the surviving pieces to fall into place under the influence of gravity and the game-play resumes.

Once all spots in the board have been filled or a player wins by obtaining, either via classically or by collapsed measurement, four cells in a row, column or diagonal, the game ends and the players have the option to play again.
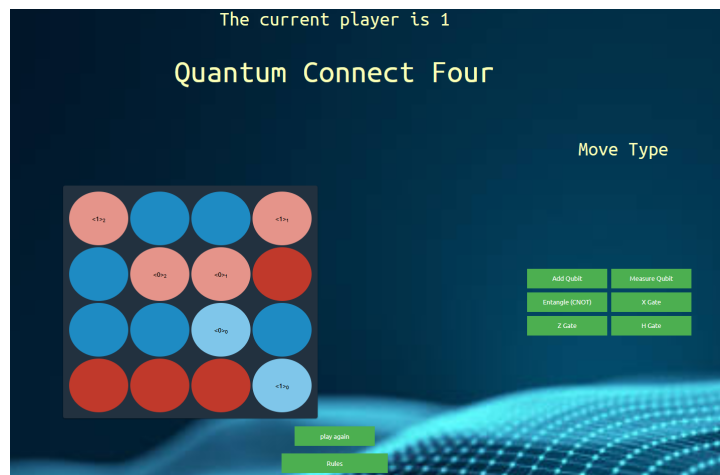
Our superposition is implemented in the backend with a quantum computer simulation that runs in quantum.py. For example, a player who wishes to superpose their cells would invoke a call to the backend to take the hadamard of the two cell positions that were passed in from the frontend, thus creating the superposed state. Later on, if the player decides to measure the state, we invoke a measurement on the superposition with 1024 shots. This replaces the superposed position with one solid cell, based on which qubit pair, 0 or 1, retains the majority of the measured counts. Note that the qubit can be reused in different cells after measurement, and it retains its original state.

Our entanglement and interference procedures work similarly. In addition to these functions, we allow the player to select individual gates (X, Z, H gates) and the CNOT gate to qubits (target must be yours). This allows us to create interesting combinations such as adding a hadamard, x gate, and cnot to create interesting entangled states.

To create more interesting strategic gameplay, we also added the rule that only pairs of qubits can be entangled, so 3 or more qubits cannot all be entangled. This makes the resulting superpositions much easier to think about and plan moves around. Also, when a qubit is measured, we also measure the qubit was entangled with it (if there was one). Since a player's qubits can be entangled with the opponents through a CNOT gate, this allows players to force each other's qubits to collapse to a classical state.

In the future, we want to expand our implementation by allowing for cells to drop, to simulate the gravity effect. We also would like to add different difficulty levels.One of these could include the option to entangle more than two qubits, resulting more complex but interesting chain reactions upon measurement. Finally, we want to implement a more durable circuit visualizer so that the circuit can grow as gameplay continues. All of these changes would allow for more interesting gameplay.

2 Demo of Game

3 Citations

https://github.com/Praveen91299/QonnectFour
https://github.com/ToJen/quantum-connect-four