# Universal Statistical Simulator

## 1 Quantum Galton Board Working

We present an intuitive method for constructing a Quantum Galton Board (QGB) that reproduces the dynamics of a classical Galton board within a quantum circuit. In a classical Galton board, a ball hitting an ideal peg has a 50% chance of deflecting left or right before encountering the next peg. To mimic this in the quantum domain, we initialize a register of qubits in the $0\rangle$ state and apply an X gate to the central position qubit, representing the ball's starting point. The evolution of the ball is simulated through a sequence of superposed swap operations, enabling it to "fall" through layers of pegs as in the physical device.

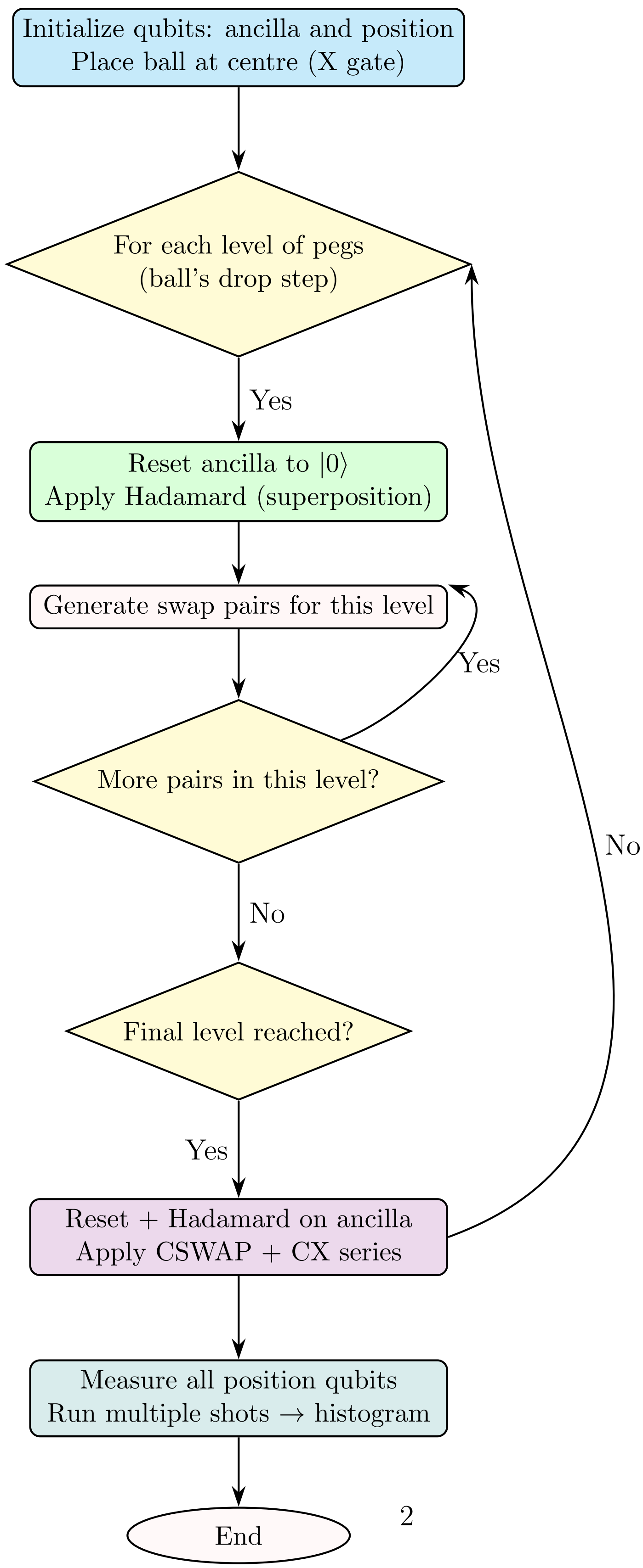
- Qubits are initialized to represent the ball's possible positions.
- The central qubit is inverted with an X gate to set the initial position.
- Superposed SWAP operations simulate the ball moving left or right at each peg.
- Peg-level configurations can be varied to control path probabilities.

By adjusting the probabilities associated with each peg, the path bias can be tuned, allowing the simulation of different statistical patterns such as bimodal, Gaussian, or exponentially decreasing distributions. This flexibility makes the QGB a versatile framework for universal distribution simulation.

## 2 Generalized QGB

- Qubits represent the ball's position; an ancilla qubit acts as a quantum coin flip.
- X gate applied to central qubit sets initial position.
- Hadamard gate on ancilla creates superposition (left/right moves).
- Controlled-SWAP (CSWAP) moves the ball based on ancilla state.
- Controlled-X (CX) updates ancilla after each move to preserve coherence.
- Repeated layers simulate multiple peg rows, producing quantum superpositions of all possible paths.
- Measurement after many runs reveals probability distribution patterns.

## 3 Flowchart Representation



## 4 Conclusion

This approach to building a QGB enables flexible simulation of diverse statistical distributions by exploiting quantum superposition and interference effects, providing a powerful platform for studying quantum analogs of classical random processes.