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Womanium & WISER Quantum Program 2025

Quantum solvers: algorithms for the world's hardest problems

Quantum Walks and Monte Carlo: Error Mitigation in a Quantum Galton Box

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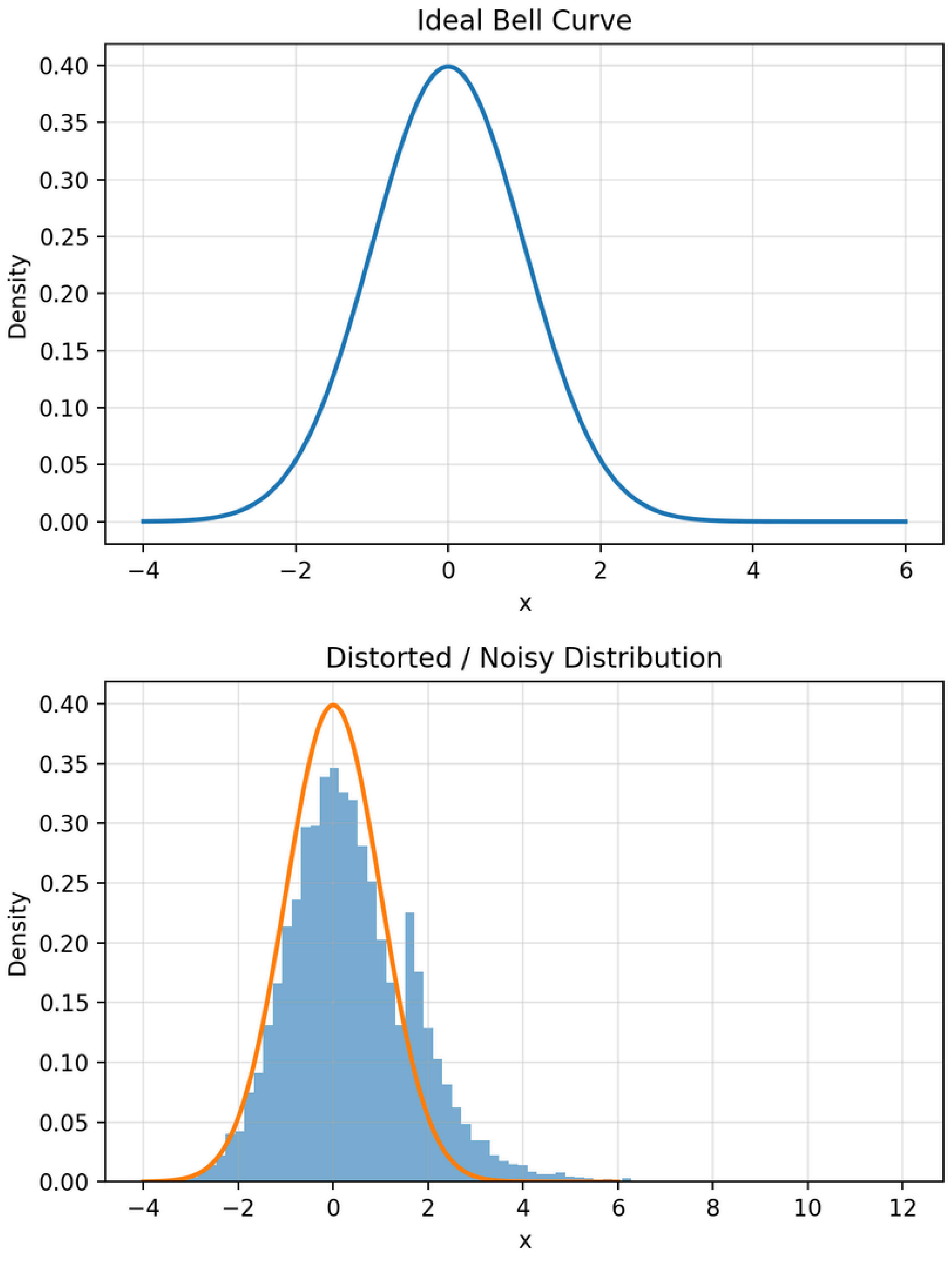

Fig. 1. a) Ideal Bell Curve b) Noisy Distribution

The Challenge: **Noise in Quantum Galton Box**

What: This project simulates a Quantum Galton Box, a model for complex random processes.

Problem: Real quantum computers suffer from noise, which corrupts results and makes simulations unreliable.

Goal: To test if a software-based error mitigation technique can improve the accuracy of a noisy simulation.

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The Approach: **Building and Optimizing a Quantum Circuit**

Objective: To build a quantum walk circuit, test it on a realistic noise model (FakeVigo), and apply error mitigation.

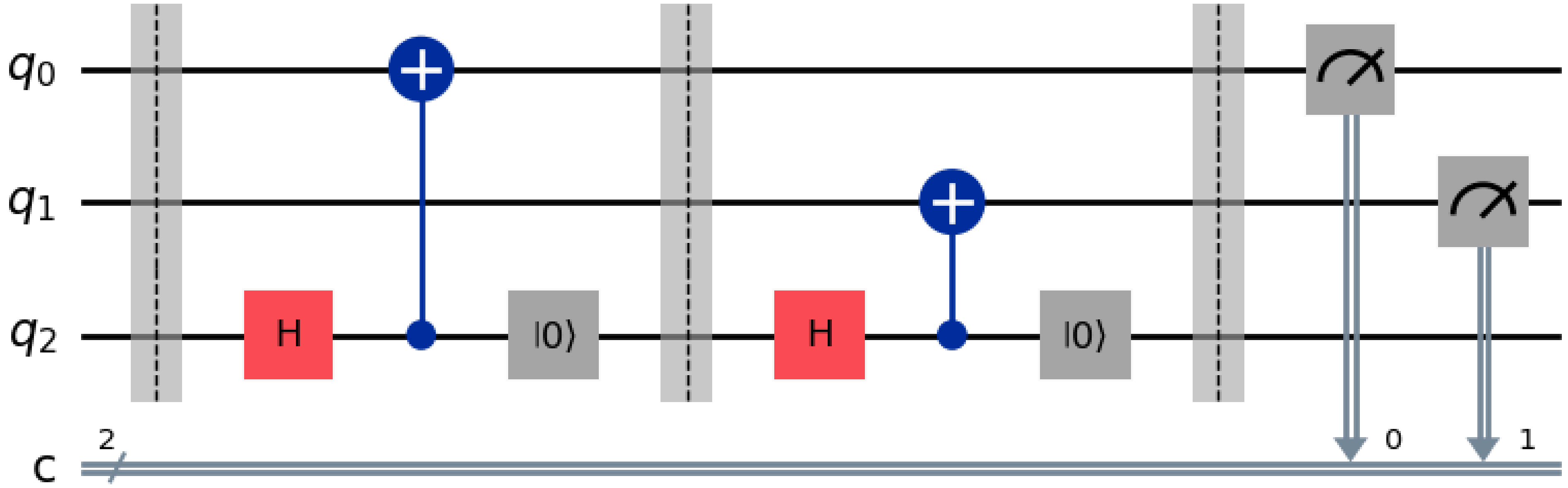

Fig. 2. A simplified 2-layer diagram of the Quantum Galton Box circuit. The ancilla qubit (q2) acts as a "quantum coin" to determine the path for the position qubits (q0 and q1).

Method:

1. Designed a circuit in Qiskit using an ancilla qubit as a "quantum coin."
2. Ran a "Noisy Baseline" simulation to measure the impact of hardware errors.
3. Applied the solution: Transpiler Optimization. This rewrites the circuit to be shorter and more efficient, making it more resilient to noise.

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Results: **Error Mitigation is Highly Effective**

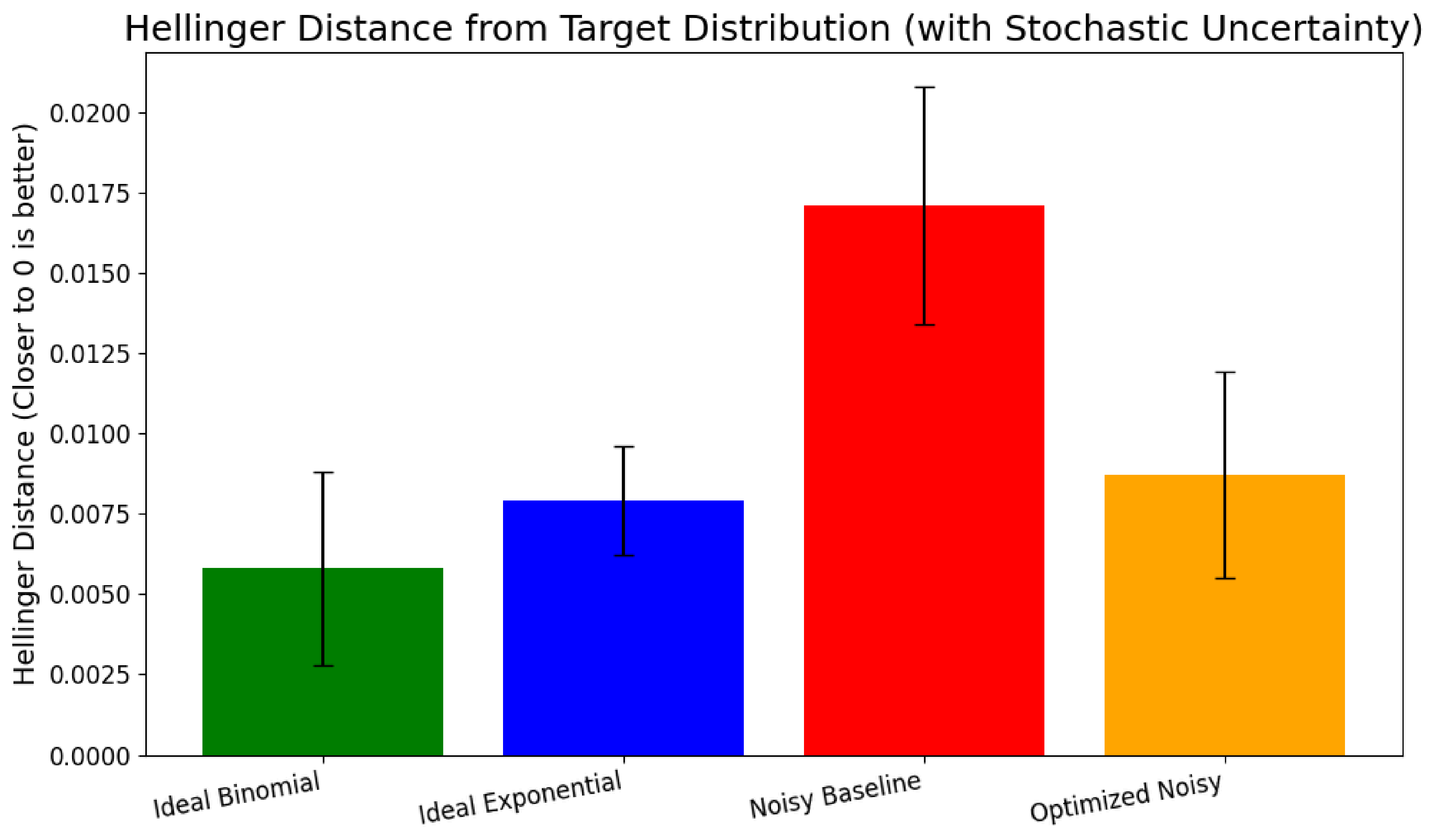

Fig. 3. The Hellinger distance from the target distribution for each simulation. The error bars represent the stochastic uncertainty (shot noise)

Success Metric: The Hellinger Distance was used to measure the error (lower is better).
Key Result: Transpilation reduced the simulation error by 49%, bringing the noisy result remarkably close to the ideal, noiseless performance.
Impact: This demonstrates that software techniques are essential for getting reliable results from today's noisy quantum hardware.

Conclusion & Next Steps

Conclusion: Software-based error mitigation is a powerful and essential tool for the NISQ era.

Future Scope:

- Run these optimized circuits on real IBM Quantum hardware.
- Implement more advanced mitigation techniques like Zero-Noise Extrapolation (ZNE).
- Explore more complex, multi-dimensional quantum walks.

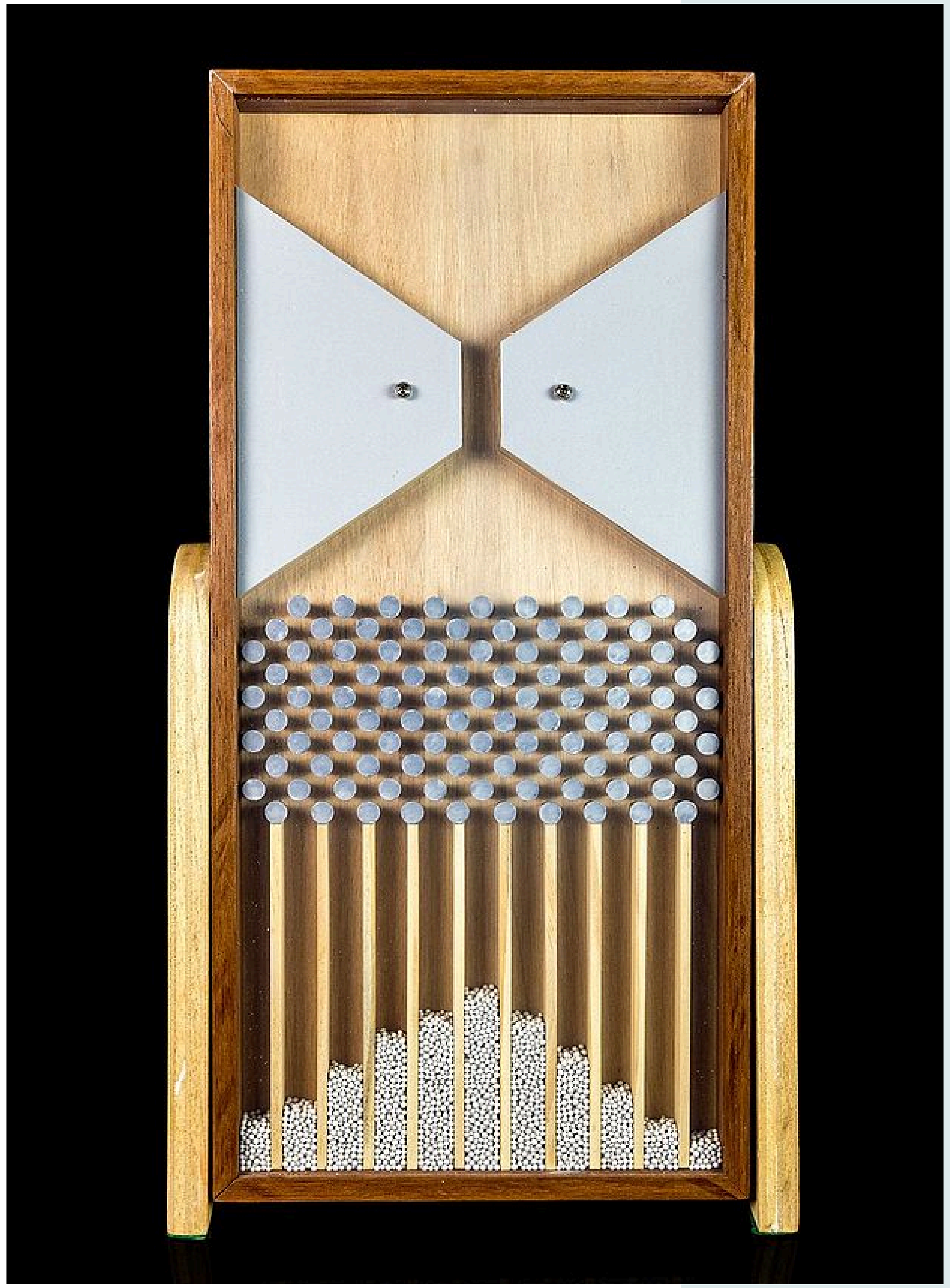

Fig. 4. Galton Box

Thank you!

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Questions?