Academic Project Portfolio

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Table of Context:

1. Project: Quantum Decoherence Simulation of Entangled GHZ States (Live Demo and Technical Overview)

This project aims to bridge theoretical quantum physics with real-world computational models. This simulation utilizes Density Matrix Formalization, allowing the modeling of non-unitary dynamics in open quantum systems. This application dynamically generates Greenberger-Horne-Zeilinger (GHZ) states for N-qubit systems and applies phase damping to simulate the environmental fragility of the system. The tool visualizes the decay of quantum coherence, tracking the decay of pure quantum entanglement into a classical statistical mixture.

I added the GitHub link of my self-study notes of MIT OCW courses.

2. Project: STM32 Development Board (Final Product and Procedure)

This is a custom STM32 development board designed, prototyped, and assembled for electronics projects. This project aims to provide a stable, sustainable product for testing the function and reliability of boards and microcontrollers designed by students. The process involves schematic design, PCB layout using Proteus, and physical fabrication using a flatiron and manually soldering all components with hand.

3. AI Remastering of MIT OpenCourseWare Lectures

While I was searching for resources to use on my self-study, I came across video lectures in MIT OCW. They were great, but their visual performance was not comfortable, so I created an upscaling workflow using ComfyUI to remaster the courses. I enhanced visual quality of Linear Algebra 18.06 by Prof. Gilbert Strang and Differential Equations 18.03 by Prof. Arthur Mattux.

Project: Simulation of Quantum Decoherence in Multi-Qubit Systems

This project aims to bridge theoretical quantum physics with real-world computational models. This simulation utilizes Density Matrix Formalization, allowing the modeling of non-unitary dynamics in open quantum systems. This application dynamically generates Greenberger-Horne-Zeilinger (GHZ) states for N-qubit systems and applies phase damping to simulate the environmental fragility of the system. The tool visualizes the decay of quantum coherence, tracking the decay of pure quantum entanglement into a classical statistical mixture.

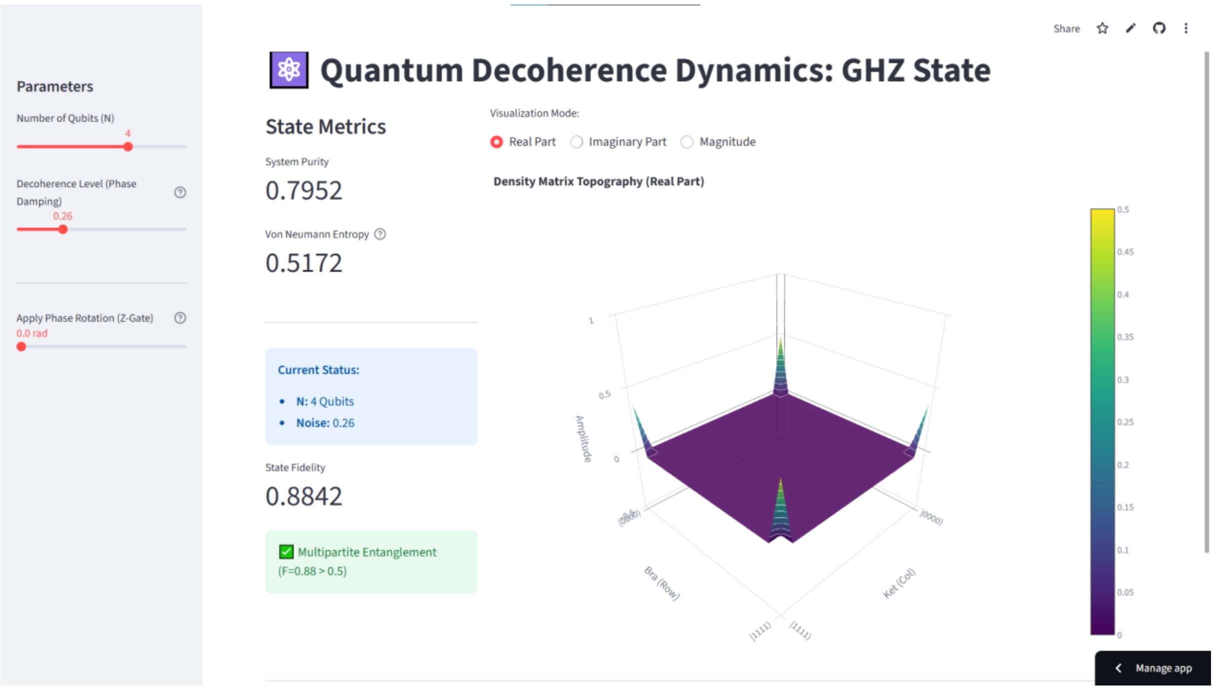


Figure 1: Interface of the quantum entanglement decoherence simulation app. The image visualizes the density matrix of a 4-qubit GHZ state undergoing partial decoherence. The central purple plane indicates the loss of coherence due to phase damping, while the sidebar metrics track the system purity, resulting increase in entropy, and state fidelity.

Technical Interpretation

This simulation utilizes the Qiskit “density_matrix” backend; the system calculates the $2^N \times 2^N$ state matrix. This allows us to derive the system purity and Von Neumann entropy.

Deriving a custom scaling algorithm to normalize decoherence probability across variable qubit counts, I ensured consistent noise modeling regardless of the system size(N).

Scalability and Benchmark

In my local execution, the algorithm handled $N \leq 10$ without any error, but the exponential RAM cost of the density matrix (4^N) caused the system to crash at $N = 12$. Due to strict resource limitations of community clouds hosting in Streamlit, this simulation is restricted to 5 qubits.

Visualization and Future Implementations

A 3D interactive surface plot renders the real, imaginary, and magnitude of the density matrix for topological interpretation.

The current version focuses on demonstrating the maximum fragility of GHZ states. I am currently working on simulating both GHZ and W to introduce comparison.

While GHZ states lose all multipartite entanglement upon the loss of a single qubit, the W-states remain entangled and preserve coherence, providing decoherence durability in quantum networks. Visualizing the comparison of both GHZ and W states provides a stronger foundation for understanding the decoherence durability in quantum networks, for both use and advantages.

GitHub Repository for Notes of Self-Studied Courses:

https://github.com/said-tng/Self-Study-Notes

GitHub Repository for Code:

https://github.com/said-tng/Quantum_Entanglement_Simulation_On_GHZ_States

Interactive Web Demo Streamlit:

https://quantum-entanglement-simulation.streamlit.app/

QR Code for Web Demo Streamlit Simulation

STM32 Development Board

This is a custom STM32 development board I designed, prototyped, and assembled for electronics projects. The goal was to create a stable, reusable platform for testing microcontrollers and circuit designs. The process involved schematic design, PCB layout using the Proteus (ISIS/ARES) suite, and a fabrication process. I transferred the circuit layout to a copper board using a flatiron with the toner transfer method, etched the board in a chemical etchant solution, then drilled each pad and soldered all components by hand.

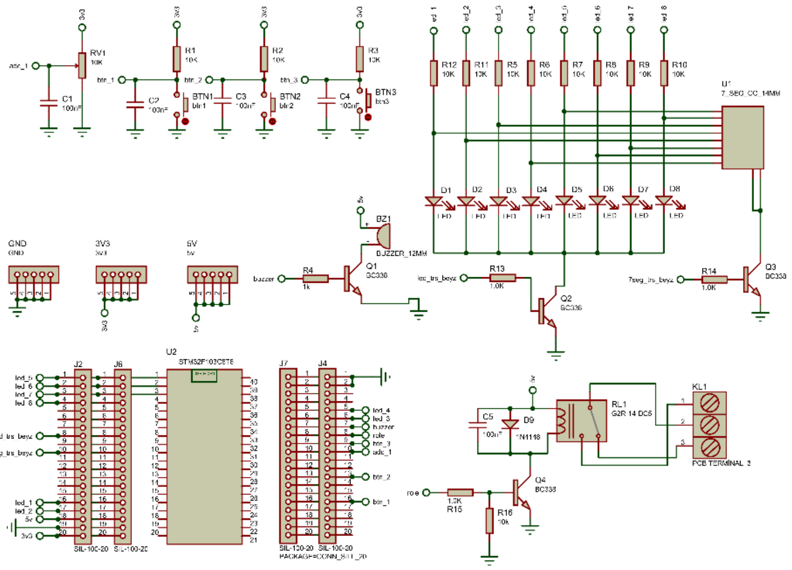


Figure 1: Circuit Schematics (ISIS). The logical design of the board, defining all components and their electrical connections.

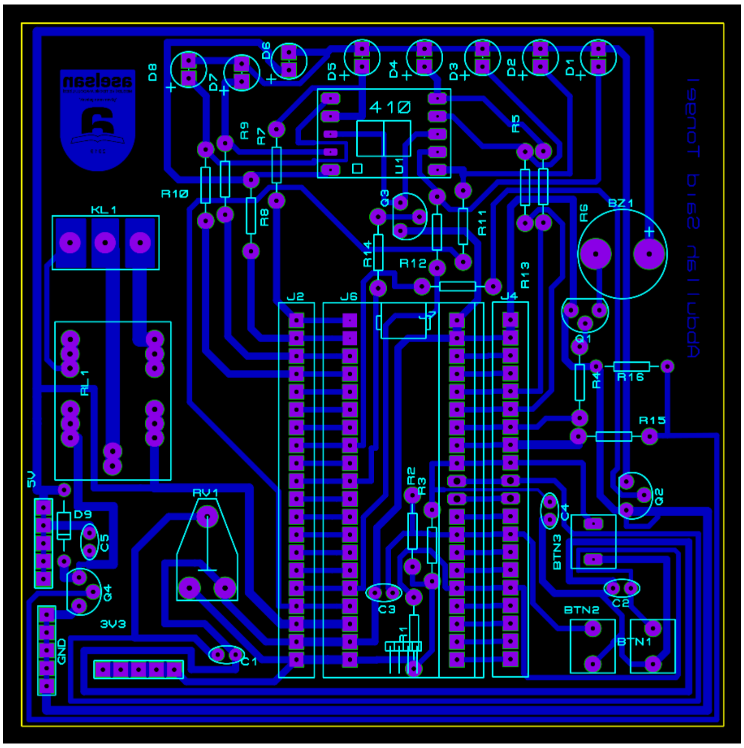


Figure 2: The PCB Layout (ARES). The physical design shows the arrangement of components and the routing of copper tracks for fabrication.

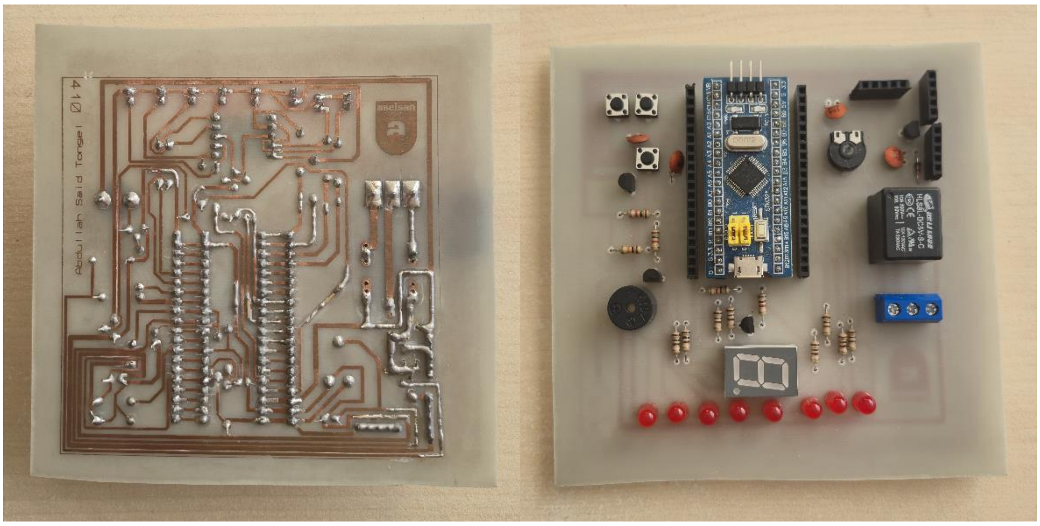
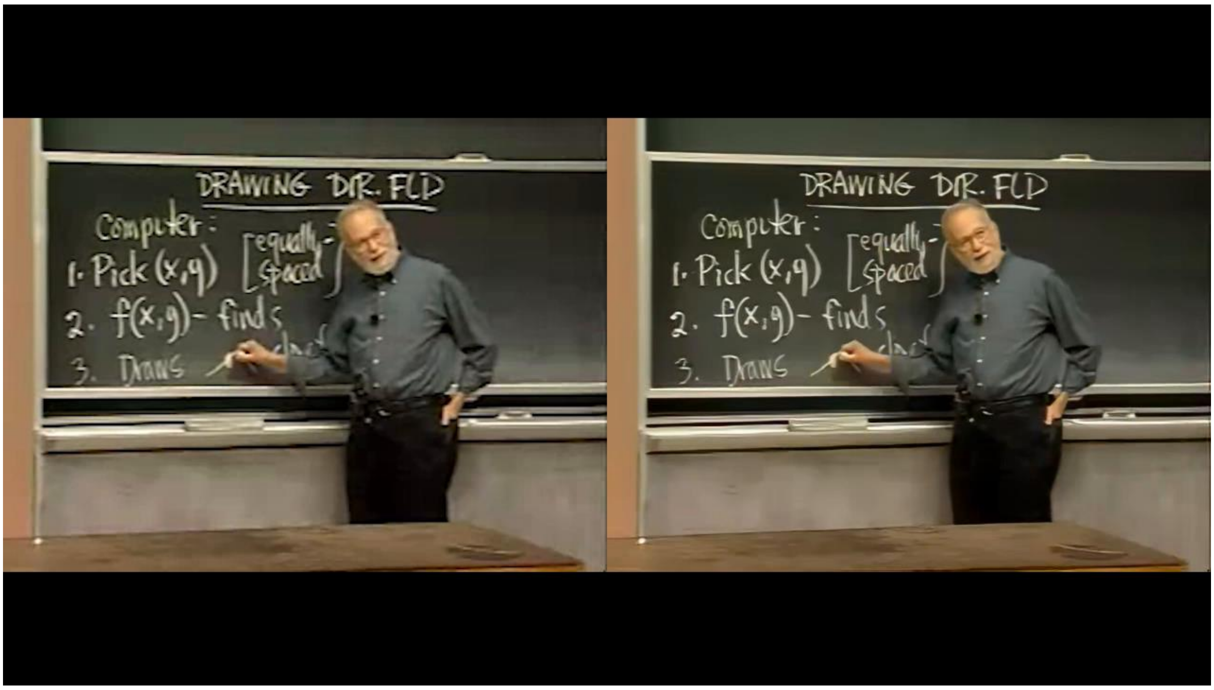


Figure 3: Final Fabricated Board (Front & Back). The completed physical prototype after etching, drilling, and soldering all components by hand.

AI Remastering of MIT OpenCourseWare Video Lectures

While I was searching for resources to use on my self-study, I came across video lectures in MIT OCW. They were great, but their visual performance was not comfortable, so I created an upscaling workflow using ComfyUI to remaster the courses. I enhanced the visual quality of Linear Algebra 18.06 by Prof. Gilbert Strang and Differential Equations 18.03 by Prof. Arthur Mattux. I tested more than 70 AI models to identify the most optimized workflow. Due to the limitations of my local machine, I deployed community cloud GPUs on RunPod to execute my work, remastering the visuals and increasing resolution by 2x, frame interpolation, and fixing video shake caused by camera movement.



BEFORE AFTER

The Links To the Upscaled Video Lectures in Internet Archive

For Differential Equations Course by Prof. Arthur Mattux

https://archive.org/details/mit-ocw-18.03-upscaled-lectures_202512

For Linear Algebra Lectures by Prof. Gilbert Strang

https://archive.org/details/ mit-ocw-linear-algebra-gilbert-strang-ai-remastered_202512