Sabneet Bains

Data Visualization – EN.605.662

Revised Project Proposal

Description

Since my undergraduate in Physics, I have been fascinated with quantum computing and progressively trying to learn more over time.

- Well, for starters, quantum computing is a domain of computing that leverages collective properties of quantum states, such as superposition, interference, and entanglement, to perform calculations. With the much hyped-up advantage being faster integer factorization than classical computers, i.e., Bye-Bye encryption! [1]

Now given the field is still analogically at the same stage as vacuum-tube computers of the 1940s, there is ongoing progress in visualizations explaining the core concepts. Thus, I propose a Tableau dashboard simulating single-qubit Bloch spheres for the following quantum gates: Pauli-X, Pauli-Y, Pauli-Z, and Hadamard.

- A Bloch sphere is a 2-D sphere in 3-D Euclidean space representing pure state basis vectors $|0\rangle$ and $|1\rangle$ at the antipodal points and mixed (entangled) states at the interior points.

- Quantum logic gates operate on qubits or quantum bits and are fundamental circuit building blocks, just like their classical counterparts.

[1] https://www.quantamagazine.org/why-is-quantum-computing-so-hard-to-explain-20210608/

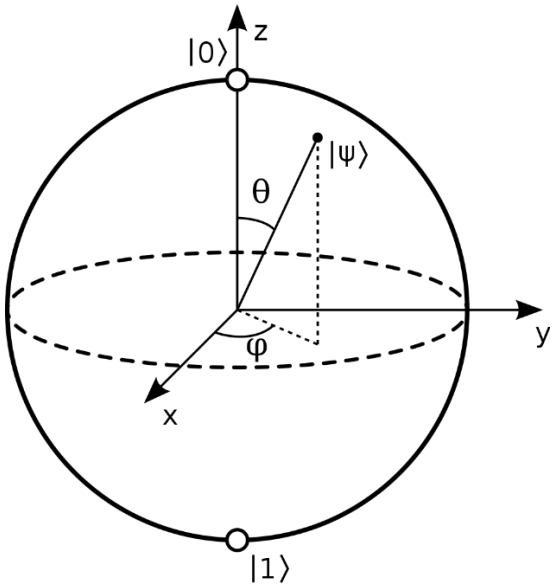


Figure 1: Bloch Sphere for a two-level quantum system [2]

The Plan

I will use Tableau 2022.1 to create a dashboard simulator with two semitransparent wire frame unit spheres, a single arrow emerging from the origin representing the state vector, and an analogous image for the quantum gate transformation.

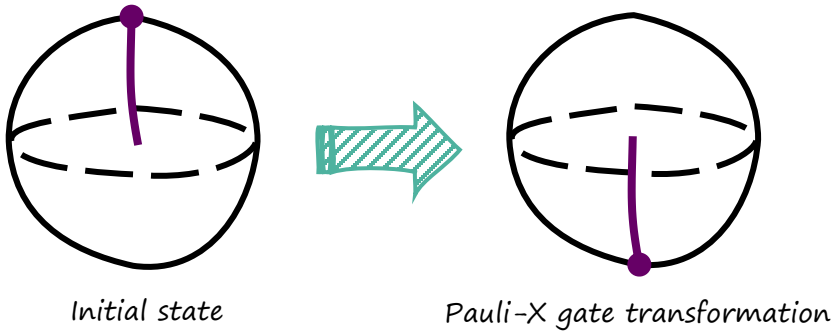


Figure 2: Bloch Spheres depicting a resultant state of a Pauli-X gate

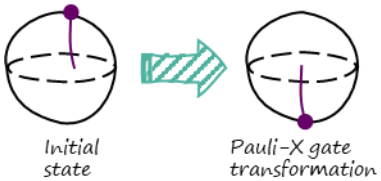
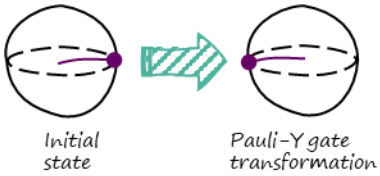
[2] https://en.wikipedia.org/wiki/Quantum_logic_gate#/media/File:Bloch_sphere.svg

Likewise, the dashboard will have a drop-down box for the four quantum gates operating on the current quantum state.

In principle, these quantum logic gates function as follows:

■ *Pauli-X:*	■ *Pauli-Y:*
$\oplus \quad \|0\rangle \rightarrow \|1\rangle$	$\oplus \quad \|0\rangle \rightarrow \quad i\|1\rangle$
$\oplus \quad \|1\rangle \rightarrow \|0\rangle$	$\oplus \quad \|1\rangle \rightarrow -i\|0\rangle$
■ *Pauli-Z:*	■ *Hadamard:*
$\oplus \quad \|0\rangle \rightarrow \|0\rangle$	$\oplus \quad \|0\rangle \rightarrow \frac{\|0\rangle + \|1\rangle}{\sqrt{2}}$
$\oplus \quad \|1\rangle \rightarrow -\|1\rangle$	$\oplus \quad \|1\rangle \rightarrow \frac{\|0\rangle - \|1\rangle}{\sqrt{2}}$

Visually, these logic gate operations can be represented in Tableau as:

■ *Pauli-X:*	■ *Pauli-Y:*
rotation around X-axis	rotation around Y-axis
	
Initial state — Pauli-X gate transformation	Initial state — Pauli-Y gate transformation

■ *Pauli-Z:*	■ *Hadamard:*
rotation around Z-axis	rotation around X & Z axes

Consequently, I can simulate the effects of these quantum logic gates on a given basis state through some basic trigonometry while providing interactive parameters.

Therefore, given throughout this project, I want to visually learn more about the effect of quantum gates on single-qubit states, I will utilize the following skills learned during the course:

- **Visual Encoding** – to neatly map a complex quantum physics topic
- **Visual Design Guidelines** – to keep the visualization consistent and minimalistic
- **Graphical Integrity** – to stay true to the underlying physics
- **Color Palettes** – to focus attention on the changes in the quantum states
- **Interaction** – to allow the user to explore different (outcome) quantum states

Timeline

A detailed timeline of each significant aspect of the project follows:

July 4th, 2022	Draft Project Proposal
July 11th, 2022	Begin revising the proposal based on instructor feedback
July 18th, 2022	**Submit** the Revised Project Proposal
July 25th, 2022	Begin researching literature
July 28th, 2022	Find four references
July 30th, 2022	Write short descriptions and a brief introduction of the bibliography
August 1st, 2022	**Submit** the Final Literature Review
August 3rd, 2022	Introduction – section introducing the research problem Background – discussing some of the previous work
August 5th, 2022	Approach – describes what was accomplished Results – describes the results
August 8th, 2022	Conclusion – concludes the paper Abstract – paragraph summarizing the paper
August 10th, 2022	Finalize the source code and finish documentation
August 15th, 2022	**Submit** the Final Project and Paper