Quantum Fractal Art for Exhibitions and Educational Purposes

QAMP Fall 2022

Project #38

Mentor: Russell Huffman
Mentees: Wiktor Mazin, Kate Marshall, David Morcuende

Qiskit

Motivation & Journey

Qiskit

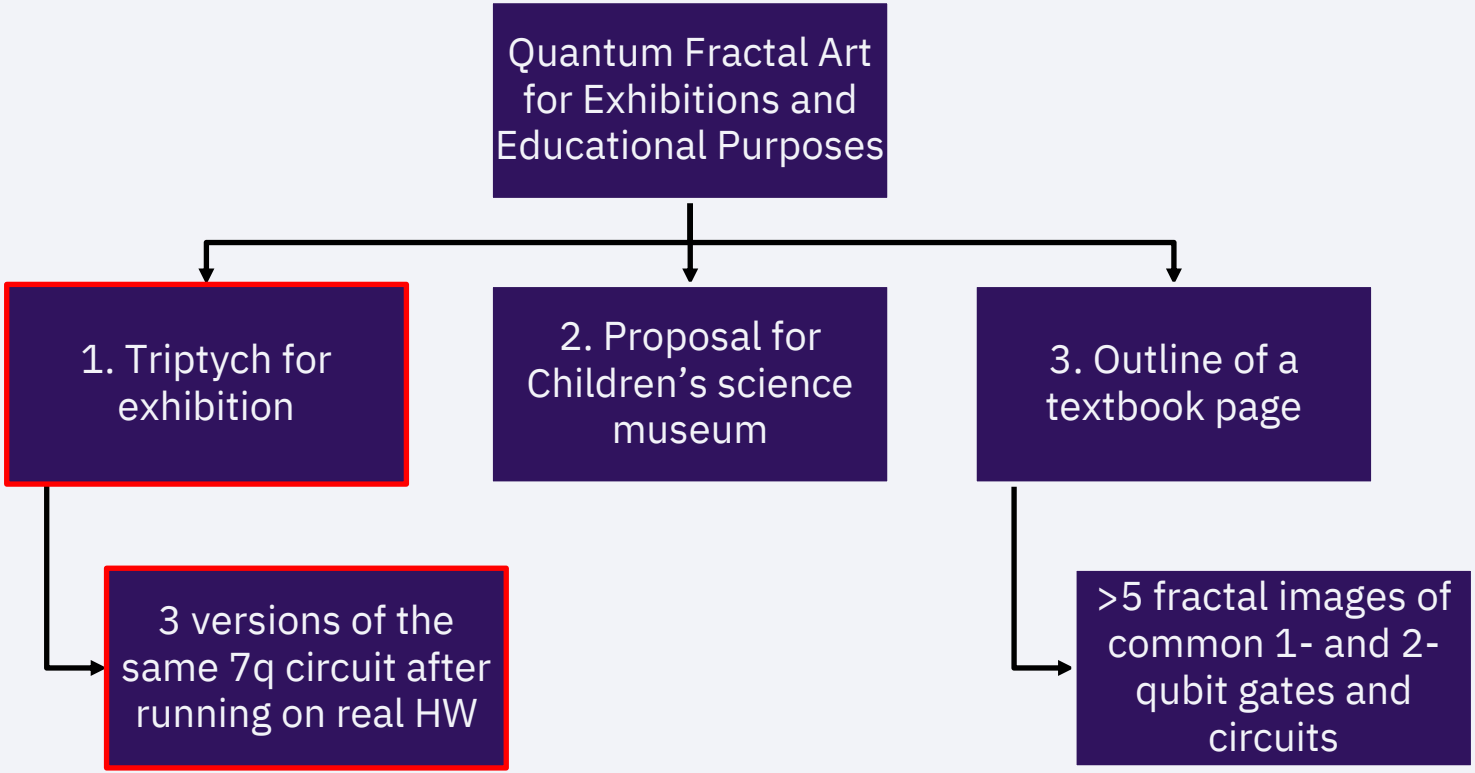
Motivation

- Fractals have the potential to be an exciting way to visualize quantum information that bridges art, science, and nature. The project builds upon previous work.
- In QAMP we decided primarily to bring unique fractals created with Qiskit to the quantum art scene, and secondarily to provide an outline of an educational textbook page with the aim of attracting a non-tech/creative audience to quantum computing.

The Journey

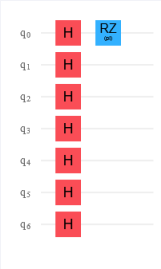
- We started by exploring fractal representations on multiple fronts; of single, 2- and 3-qubit gates & circuits, and >3-qubit circuits. This included the Bell states and Quantum Teleportation.
- We experimented with 2D and 3D versions of the fractals in Blender while looking for a way to get high resolution versions.
- We decided on a triptych for an art exhibition, requiring work generated on a real quantum computer, and a proposal for children's science museums has also been drafted.
- Finally, we created an outline for a Qiskit textbook page and a children's science museum proposal.

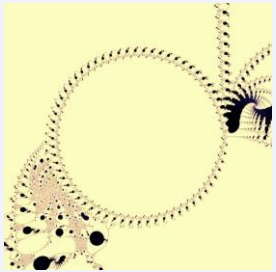
Summary of the project



Triptych for exhibition

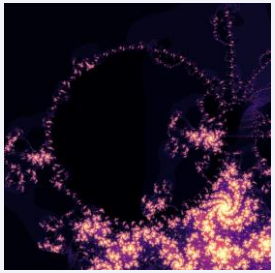
- Approach: Experimenting with multi-qubit circuits, we discovered many amazing and unique fractals. One of these was created based on a 7q-circuit which resulted in the simulated “Qubit Carousel” fractal:



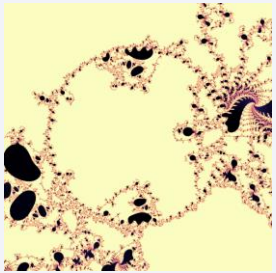


- The Qubit Carousel was run on real 7q quantum computers, and we decided to go for the triptych:

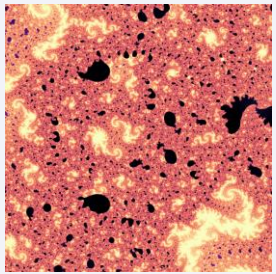
Wiktor



David



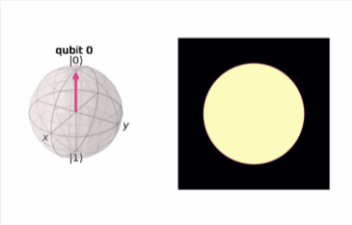
Kate

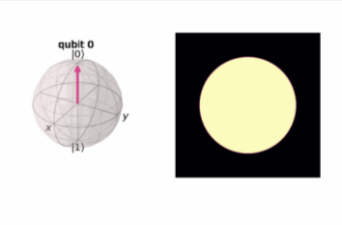


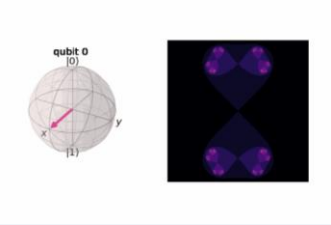
- The triptych is destined for an art gallery in NYC, early 2023.

Proposal for Children's science museum

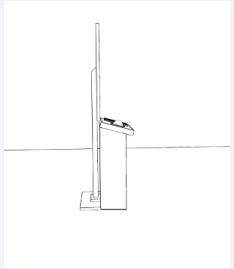
- Title: *Interactive Quantum Art Station*
- Description: *Our aim is to offer an alternative, visual way to understand quantum states and circuits, which are notoriously difficult to conceptualize. In this booth exhibit, a user can interact with a one-qubit fractal representation of a state using a keypad and interactive mouse, to see how their movements impacts the quantum state.*

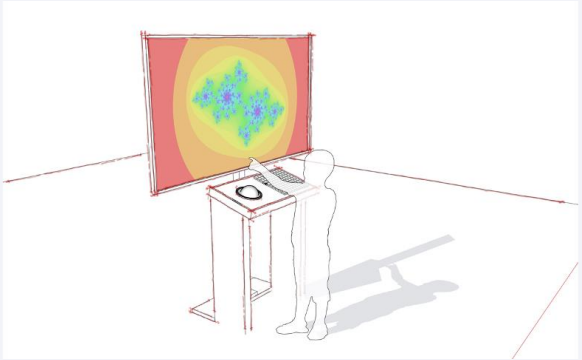






We can see from some sample images of rotations around X, Y and Z axes, the different shapes that the fractals assume.





Outline of a textbook page

Qiskit

Our idea is to explain quantum states and the mathematics behind them through visual representations using fractals.

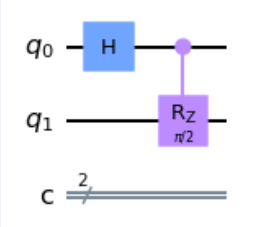
Draft outline:

1. Introduction incl. mathematical explanation of concepts [with explanations of terms + quizzes]
   a) Why use fractals as visual representations of quantum states?
   b) Fractals in nature
   c) Fractals (Julia sets) and complex numbers
      i. Interactive widget with brief explanation: Bloch sphere & 1-qubit fractal
   d) Complex amplitudes and state vectors
   e) More advanced fractals with Julia set mating (2 + 3 qubits)
      i. Tab blocks with 1, 2, and 3 qubit fractal images
2. Inline code with option to run on both simulator and real HW, using the Circuit Composer.

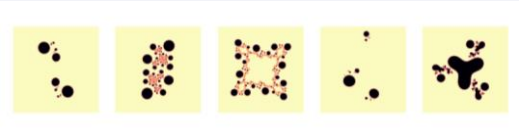
We use Julia set mating like the one described below to generate the images and animations

$$z[m] = \frac{z[m]^4 + c_2[m] \cdot z[m]^2 + c_0[m]}{z[m]^4 + c_3[m] \cdot z[m]^2 + c_1[m]}$$

for example this circuit with 2 qubits



can generate this animation



Summary

Qiskit

Results

- ✓ > 5 fractal images of common 1- and 2-qubit gates and circuits.
- ✓ Identified at least one art exhibition that has expressed interest in displaying the quantum gate fractals.

Future work

- Confirm interest from a children's science museum.
- Finalize textbook page
  - Project writeout wrt the textbook page
- Blog after the exhibition