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Art makes quantum intuitive

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1 Introduction

Not so long ago, humans were a group of primates living on the savannah. We are reasonably proficient at estimating the trajectory of medium-sized objects, such as falling rocks and arrows, moving at moderate speeds. However, one must acknowledge that our intuition falters when it comes to understanding the behaviour of micro objects moving at very high speeds.

Consider, for instance, the famous double-slit experiment. If you throw a ball towards two slits, the ball will pass through one slit, according to a common-sense prediction. However, when small particles, such as photons or electrons, are projected through two closely spaced apertures, the result is as if the particles simultaneously pass through the two apertures. In quantum physics, this unintuitive observation is explained by the wave-particle duality. It means that, physical entities can possess wavelike as well as particle-like characteristics. The duality is analogous to the two sides of a coin; the same reality can be described from different perspectives. Unfortunately, this knowledge does not cause that quantum mechanisms are entirely understandable and intuitional. Therefore, the following question remains open, how can we define quantum art when we are unable to fully grasp quantum mechanics?

On a similar note, art itself is challenging to understand, albeit for different reasons. It is widely accepted that art is, to a significant extent, a subjective experience. An artist creates a piece of art that evokes diverse emotions and interpretations when presented to different people. Consequently, how can we bridge the gap between quantum mechanics, which is primarily comprehended through mathematics, and art, which is intuitively understood without the need for conscious reasoning? In other words, how can quantum art make the enigmatic world of quantum more intuitive and accessible?

To address these questions, we created a challenge for the HackYeah! hackathon, one of the most prominent stationary events in Europe. We invited people to find an artistic way to illustrate the principles of quantum mechanics, including quantum superposition, entanglement, and decoherence. Approximately 700 individuals attended the event. Multiple challenges were submitted by different companies, and the Quantum Art challenge was chosen by 15 teams that ranged in size from two to seven people. After a short description of the challenge in Section 2, we explore some of these contributions in Section 3. Lastly, Section 4 concludes the paper. In our opinion, the artwork presented, especially the visual ones, helped to makes quantum principles more understandable, intuitive.

2 Challenge

The purpose of the challenge was to find an artistic way to illustrate quantum mechanics, specifically quantum superposition, entanglement, and decoherence.

Quantum superposition refers to a phenomenon where a single particle can exist in two states simultaneously. In contrast to a 'normal' bit, which can be either 0 or 1, a quantum bit is a superposition of both 0 and 1.

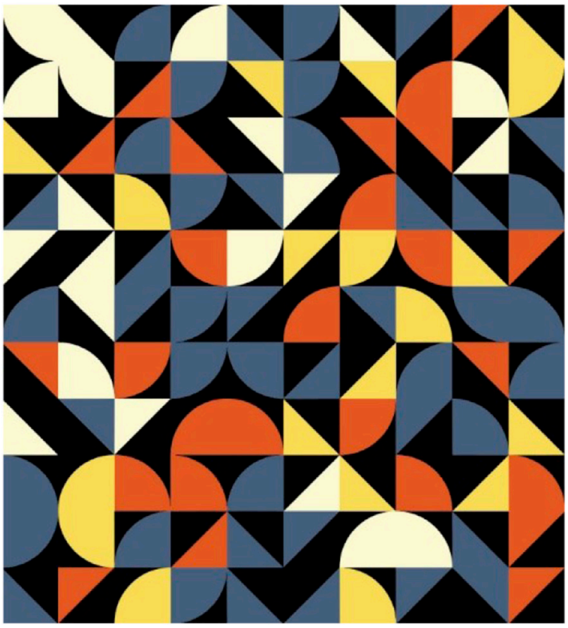

FIGURE 1
Art generated by the Quantum Mosaic team.

The measurement operation is the process through which a quantum state is collapsed to either the state 0 or 1. Let us consider two quantum bits; the possible measurement outcomes can be one of the following four combinations: 00, 01, 10, or 11. When only two of these combinations are possible, such as 00 and 11 or 10 and 01, one can state that the quantum bits are entangled because the state of one qubit affects the state of the second qubit and *vice versa*.

Decoherence of the quantum state is an effect that results from microscopic interactions between the quantum bits and the environment. This environmental noise impacts the state of the quantum bits and can lead to errors in computation. In other words, multiple measurements of the same quantum computation may yield different results. Different quantum computer architectures exhibit varying levels of noise.

Here, the following question arises: How can people represent the principles of quantum mechanics in a way that it is tangible, visible, or even audible?

3 Artworks

In this section, we present a selected panel of examples that were implemented during the HackYeah! hackathon.

3.1 Quantum mosaic

This project effectively demonstrates the concept of quantum decoherence. It showcases a mosaic in which the arrangement of image elements is determined by the outcomes of quantum measurements (Figure 1). Various mosaics are generated following these measurements and are subsequently combined into an animated GIF. Notably, the greater the instability of the quantum computer, the more pronounced the glitches become within the mosaic.

As a testament to its excellence, this project emerged as the winner of the challenge. The project is available on GitHub at https://github.com/lukilesny/quantmosaic.

3.2 Quantum vortex art

This code is based on the previous quantum art of Wiktor Mazin,[1] which exploits the Julia fractal set for image generation. Julia fractals are fractals based on a recursive suite of a complex number.

The code performs a straightforward computation that involves the measurement of two qubits. The probabilities of these qubits being in either state 0 or 1 are employed to initialise the real and imaginary part of the complex numbers in the Julia set. The resulting Julia fractal is presented as an image, which is then further customised through user input. This customised image is subsequently passed to the text-to-image artificial intelligence model Stable Diffusion to create both personalised and quantum artwork.

This project also illustrates the concept of quantum decoherence. The project is available on GitHub at https://github.com/Havystar/QUANTIUM.

3.3 Quanter point

This work is also inspired by the contributions of Wiktor Mazin; however, it diverges by focusing on the creation of music rather than images. It resonates with the European project on Quantum Music[2] (e.g. (Putz and Svozil, 2017)), with the distinction being that instead of encoding notes into quantum states, it employs fractals to generate eight distinct musical notes.

The project is available on GitHub at https://github.com/kmazrolina/Quanterpoint.

3.4 Quantune

This project is also an application of quantum music. It breaks down musical compositions into 4/4 tempo measures. Each measure is encoded using a set of four qubit quantum circuits, with each quantum bit symbolising a distinct musical element, encompassing notes, rhythm, and pauses. Diverse variations of a melody are generated, each of which is closely tied to a specific quantum architecture. It is akin to experiencing music through a quantum lens that unveils the distinctive quantum voice of each architecture.

The project is available on GitHub at https://github.com/git-stashic/quantum-art.

1 https://github.com/wmazin/Visualizing-Quantum-Computing-using-fractals

2 http://quantummusic.org/

3.5 Quantium

This project serves as an in-depth exploration of variational quantum circuits (VQCs) applied to the classification of the IRIS dataset. The classification results are then presented through Seaborn graphs (a library for scientific visualisation). This project is classified as scientific visualisation rather than art, but the effort merits our attention. A similar approach with VQCs can be observed in the pyRiemann-qiskit library (Andreev et al., 2023), as showcased in the library documentation[3]. In this example, the learning parameters of the VQC are ingeniously illustrated as a spiral, with each branch signifying the variation in weight of a specific parameter.

Additionally, the project delves into Bubble Art, drawing inspiration from the work of Radha Pyari Sandhir[4]. The core concept involves encoding a string into qubits and subsequently measuring the outcomes of computations performed on them. The resulting measurements are then transformed into bubbles. The size and number of bubbles convey information, with smaller, numerous bubbles indicating more noise, while larger bubbles represent measurements that yield the same results.

The project is available on GitHub at https://github.com/dr3du4/Quantium.

3.6 Quantum variational autoencoders

Autoencoders are a class of neural networks that are commonly employed to extract an efficient representation of specific data, akin to dimension reduction techniques. In this particular scenario, the team proposed the use of a variational autoencoder, with its parameters initialised with the measurement of a quantum circuit.

The autoencoder's purpose is to learn a concise representation of a cat by using the Kaggle CAT dataset. Dimensionality reduction essentially serves as a means of compressing the data, resulting in a deliberately artistic blurring or fuzziness effect on the original image.

The project is available on GitHub at https://github.com/polish-mountain/quantum-vae.

3.7 Quantum brain art

Here, the concept revolves around the initialisation of a quantum circuit with brain wave frequencies, such as alpha and beta waves. Quantum operations are run on these states, and the outputs are measured in classical bits. Then, the resulting measurements are translated into values of saturation and luminance, ultimately contributing to the customisation of a piece of artwork.

Essentially, it can be described as an electroencephalography (EEG) state personalised through quantum randomness. What makes this idea particularly intriguing is its potential for expansion. By introducing different qubits that represent the mental states of other users, brain synchronisation could be further represented by entangled states. When two users are competing or cooperating to solve a task, the synchronization between their mental states only allow for certain measurement probabilities, which is akin to a form of entanglement.

This notion also resonates with the concept of the quantum brain hypothesis (Tarlacı and Pregnolato, 2016), according to which the brain coexists in multiple states simultaneously, which subsequently collapse. In this idea, EEG measurements become a measurement of these quantum brain states, and the task executed by the user while recording the electroencephalogram could be further represented by specific quantum operations. Just to be clear, we do not pretend that this is actually the case, but this project could lead to interesting metaphors between brain states and quantum representation.

The project is available on GitHub at https://github.com/kinga-marszalkowska/QuantumBrainArt.

4 Conclusion

Various artistic viewpoints were submitted as part of the Quantum Art challenge at the HackYeah! hackathon, including images, animations, and music. By far, quantum decoherence—that is quantum noise—was the most exploited quantum concept. While quantum superposition was used internally, it was not—in our opinion—sufficiently highlighted by the presented artworks. As for quantum entanglement, it was explored under the concept of quantum music. Apparently, it is not always intuitive for people to understand quantum entanglement simply by hearing music. Saying that, you need a certain level of knowledge to build appreciation. For example, children need to learn different tastes to appreciate food.

Among the aforementioned works, we noticed the use of quantum principles for creating artistic visualisations of mental states through EEG, as well as the use of art to enhance the visualisation of machine learning techniques. Here, we see art's potential to enhance the comprehensibility and natural intuition of quantum phenomena. This is an interesting approach to make quantum more accessible, intuitive, especially for neophytes.

The question that lingers is whether visualisation truly qualifies as art. The answer is nuanced and may rely on the intent itself. A good visualisation can be a piece of art if the machine learning model was created with the sole purpose of producing art rather than for merely explaining a machine learning algorithm.

Another perspective is that of Japanese contemporary artist Matsuzawa Yutaka (1922–2006), although we admit that we have not had the opportunity to read the original Japanese text. Our understanding is based on the writings of Alan Longino from the Department of Art at the University of Chicago (Longino, 2019):

> "Trough Quantum Art, Matsuzawa invited future readers, viewers, and participants to conceive of a world where objects, bodies, images, and matter become less defined, more permeable, and bound together in limitless intimacy".

In essence, the artist's manifesto is a call for renewal, a break from artistic conventions, similar to the role of quantum physics in the physical sciences.

3 https://pyriemann-qiskit.readthedocs.io/en/latest/auto_examples/toys_dataset/plot_quantum_art_vqc.html#sphx-glr-auto-examples-toys-dataset-plot-quantum-art-vqc-py

4 https://medium.com/qiskit/how-i-use-quantum-computing-to-create-bubble-art-d6c01f3ec2e

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References

Andreev, A., Cattan, G., Chevallier, S., and Barthélemy, Q. (2023). pyRiemann-qiskit: a sandbox for quantum classification experiments with riemannian geometry. *Res. Ideas Outcomes* 9. doi:10.3897/rio.9.e101006

Longino, A. (2019). Psi towards vanishing. Matsuzawa Yutaka exhib text. Available at: https://www.academia.edu/43027932/Psi_Towards_Vanishing (Accessed September 4, 2023).

Putz, V., and Svozil, K. (2017). Quantum music. *Soft Comput.* 21 (6), 1467–1471. doi:10.1007/s00500-015-1835-x

Tarlacı, S., and Pregnolato, M. (2016). Quantum neurophysics: from non-living matter to quantum neurobiology and psychopathology. *Int. J. Psychophysiol.* 103, 161–173. doi:10.1016/j.ijpsycho.2015.02.016