Quantum Generative Art

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Abstract

Representation of the world has been an important task entrusted to artists since the beginning of time.

However, since the beginning of the twentieth century, physicists have made an enormous advance on the deep understanding of our world: it is not only classical, but also quantum.

This fabulous discovery allowed some pioneers to create works inspired by quantum technologies. And with the very astonishing phenomena of superposition of states, entanglement of particles and even teleportation.

Since Richard Feynman's brilliant idea in the 1980s to create a quantum computer, progress has been spectacular in this area. [11]

Many quantum algorithms have seen the light of day (Grover, Shor, etc.), and today tools are available to really write computer code with the principles of quantum mechanics.

Generative Art precisely uses computer code to create works of art. It is a great chance now to have new totally innovative tools to experiment and create with quantum gates (Hadamard, Pauli, Toffoli, etc.) which replace our good old logic gates known since the beginnings of classical computing.

In this article, we propose to take a quick historical tour of the use of quantum computing in Art. Then, we show how to use these new quantum tools to achieve original generative creations, whether for images, 3D sculptures or animations.

We use the famous Schrödinger equation to generate quantum animations.

Finally, we are interested here in Quantum Generative Adversarial Networks, which are extremely powerful and modern tools for generative creation.

The pioneers of quantum art

If the concept of a quantum computer dates to the 1980s, it was not until the 2000s to see the first quantum generative artistic works.

Among the very first, Antony Gormley, produced the Quantum Clouds in 1999, a monumental sculpture exhibited in London. (Fig 1).

Fig 1: Antony Gormley, Quantum Cloud, 2000. (© Antony Gormley).

We can also cite the works of Julian Voss-Andreae, notably his works "Quantum Man" (2007) and "Night Path" (2009), who was one of the very first artists to create with quantum computing. (Fig 2).

Fig 2: Quantum Man 2007. (© Julian Voss-Andreae. Photo: Dan Kvitka.) The image shows a superposition of two views of the same sculpture.

Let us quote the remarkable work of Lynden Stone, who from 2013 tries to describe what the work of quantum artists represents, and how to see reality differently, with the notions of superposition that automatically lead to quantum computing. [13].

She describes experimental quantum works of Jonathon Keats, who in 2011 is the first to make a generative quantum installation, "Quantum Entanglements".

Fig 3: Jonathon Keats, Quantum Entanglements, 2011, installation shot. (© Jonathon Keats)

Daniel Crooks (2010) and Alain Lioret (2013) with Time Beings [10] are also part of these pioneers who explore new generative methods of creation with the new tools made available with quantum computing.

Alain Lioret has been working on numerous experiments since now using real quantum computers (those offered by IBM in particular) through the Qiskit module. [7] [9].

Another essential artist in the field is Libby Heaney who has more recently started to create quantum works [14]. Several major quantum works are part of his artistic work, including “Cloud” in 2015.

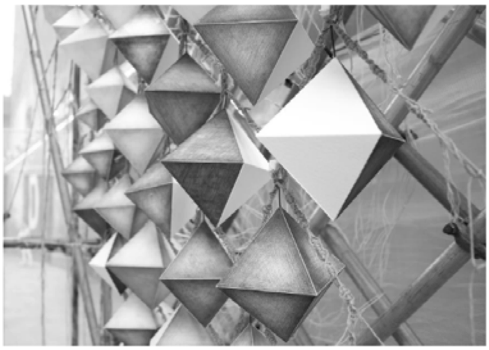


Fig 4: CLOUD showing graphite and white octahedrons, 2015. (© Libby Heaney)

3D Quantum Creations with Quantum Nodes

We propose an integration of quantum algorithms in the 3D creation process. Our objective is to enable quantum circuits manipulation in the 3D software Blender while integrating this tool into its already existing 3D pipeline.

Our tool is developed in Animation Nodes, a node-based visual scripting system designed for motion graphics in the 3D software Blender. It is within this add-on that we have integrated nodes related to quantum computing using the Qiskit python library.

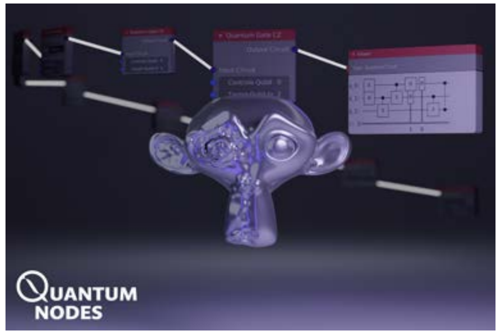


Fig 5: Quantum Nodes. (2021)

A quantum circuit can be represented as a data stream (input – computation – output), just like nodal programming in 3D software’s, which makes its implementation as nodes natural. In addition, this solution is in line with the “everything is node” trend that is currently taking place in the 3D creation industry. [8]

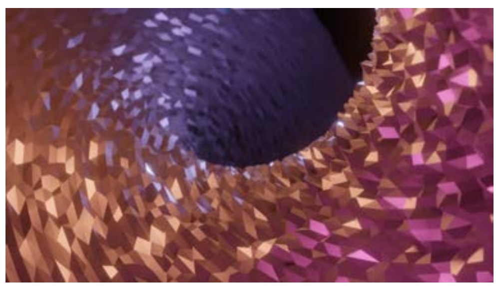
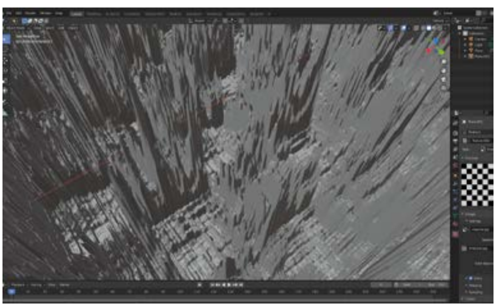


Fig 6: 3D creation with Quantum Nodes (2021)

2D Schrödinger equation simulation

This have also implemented a node of a 2D simulation of the Schrödinger equation.

The node outputs the state of the simulation at the current frame. All the simulation data are stored for each frame. Whenever a parameter changes, all the data for the current simulation are deleted. The simulation depends on all the previous frames. So, if you suddenly ask for a frame that was not already computed and that is "far" from the last computed frame, the simulation can take a few seconds to compute this frame (since it must compute all the previous frames).



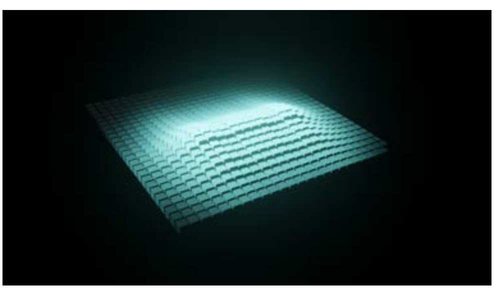


Fig 7: Creations using the Schrödinger equation node. (2021)

Quantum Generative Adversarial Network

In artificial intelligence, generative adversarial networks (GANs) are a class of unsupervised learning algorithms. These algorithms were introduced by Goodfellow et al. 2014. They allow images to be generated with a high degree of realism.

A GAN is a generative model where two networks are placed in competition in a game theory scenario. The first network is the generator, it generates a sample (e.g., an image), while its opponent, the discriminator, tries to detect if a sample is real or if it is the result of the generator.

The arrival of quantum computing is revolutionizing many fields, particularly that of artificial intelligence

GANs are no exception, and we now see the appearance of QGAN: Quantum Generative Adversarial Network. [1] [2] [3].

A QGAN uses two parameterized quantum circuits, the discriminator, and the generator. The wonderful part of GANs, which relates to QGANs, is that we use the discriminator drive signal to drive the generator!

Our two quantum circuits maximize and minimize the same optimization problem in this zero-sum game, which we will formalize in a few minutes.

After many learning steps, the generator learns the optimal parameters to pass through its quantum gates. It spits out a quantum state which is approximately equivalent to the quantum state representing real data.

The generator learns the actual quantum data only through the discriminator training signal.

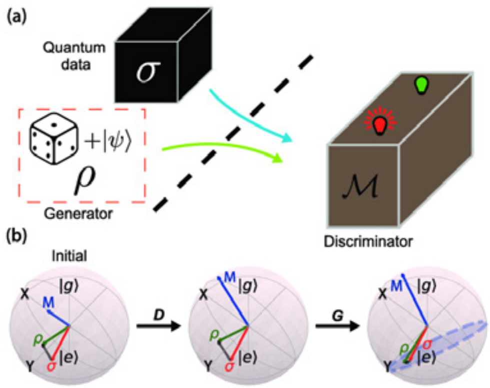


Fig 8: A QGAN structure

First, the discriminator tries to improve its strategy, while the generator strategy remains fixed. Then, they change turns, and the generator tries to improve its strategy, the discriminator strategy being fixed. These two players continue to update each other for hundreds if not thousands of eras until the fixed point is reached. We call this point the Unique Nash Equilibrium, just like conventional GANs.

The QGAN has completed the training once the trained discriminator cannot reasonably distinguish between generated / real quantum states (50% probability of correct classification). In this case, the quantum states (technically density matrices) of the generator and the actual data distribution are approximately equivalent.

The use of QGANs allows us to envision even more amazing creative generative experiences. Quantum Generative Art is still in its infancy.

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