

# Quantum Computer Art

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## 1 Quantum Computer Art Studies

This project is an artistic practice that treats the quantum computer as an expressive medium for manipulating material quantum states. The works were produced through computations carried out on a 64-qubit superconducting quantum computer installed at QIQB (Center for Quantum Information and Quantum Biology), The University of Osaka.

The states of qubits inside a quantum computer cannot be directly perceived by humans, nor can qubits be copied. What we can access is limited to fragmentary, statistical classical information obtained through repeated measurements of fundamentally unknowable states. In this project, the classical “images” that emerge from many measurements are regarded as shadows of a lost whole, and the randomness, noise, and errors intrinsic to quantum computation are embraced as aesthetic elements.

Classical computer art has generally presupposed stable algorithms and reproducible outputs. In contrast, quantum computer art cannot escape non-repeatability and multiplicity, non-determinism and unknowability, or material fluctuation. Quantum computer art is thus a once-in-a-lifetime event: a momentary manifestation of a quantum state as an original form (Urform), woven from multiple states and appearances.

A booklet summarizing the results from the first half of 2025 was presented in August 2025 at the curated exhibition *Entangle Moment — [ Quantum | Earth | Universe ] × Art*, held at Expo 2025 Osaka, Kansai, Japan. In this phase, the project proposed a framework of “Quantum Information Aesthetics” by connecting Max Bense’s information aesthetics with quantum information theory, asking what it means to aestheticize the imperceptible. Aesthetic experience is understood here as plastic and mutable, and aesthetics is redefined as a technique for inducing cognitive transformation and sensory reconfiguration through encounters with quantum states.

The project then explored the “Quantum Chip Bitmap,” in which the physical layout of a

quantum chip is treated as a canvas and pixel images are drawn through quantum gate operations. On a chip cooled to near absolute zero, quantum gates function as “traps” for qubits, capturing their measured results as shadows. Pixel noise and missing data are not defects but traces of the qubits’ physical existence and their interactions with the environment.

In this exhibition, the project further experiments with “Quantum Color Composition,” which maps qubit states onto color spaces. Through processes of generation and appreciation, it investigates the behavior of qubits detached from human perception and the colors that arise from repeated measurements. This practice marks an intersection of quantum technology and culture, while also proposing another mode of art for living with the unknowable. Here, art becomes an experimental field for dismantling and reinventing perception, asking how unknown realities might be constructed through sensory experience.

## 2 Quantum Chip Bitmap

Pixel images created through direct manipulation and measurement of qubits arranged in an 8×8 grid on the quantum chip of a superconducting quantum computer.

- Two Humans 250718
- Heart 250718
- Heart filled with Superposition 250711
- Peace 250711

### 3 Quantum Color Compositions: The Color of the Imperceptible

The colors we ordinarily perceive are produced when objects emit light, or when light is reflected by objects and interpreted by the human visual system. In contrast, in the quantum world, the photons that give rise to color do not possess a definite state until a measurement is performed. “The color of the imperceptible” asks about the possibility of “latent color”—colors that may be inherent in quantum states prior to measurement.

In this project, the Bloch sphere, which represents the state space of a qubit, is mapped onto the HSV color space as a means of color expression, enabling experiments in color composition based on quantum computation. The phase  $\phi$  on the Bloch sphere is mapped to hue, the purity of the state  $|r|$  to saturation, and the parameter  $\sin(\theta)$ —corresponding to measurement probability and the capacity for interference—to brightness (value).

The state of a qubit is estimated through quantum state tomography. Many identical quantum states are prepared and measured in three bases—X, Y, and Z. From the resulting statistics, the pre-measurement density matrix (quantum state) is reconstructed, allowing the color of the qubit to emerge. In quantum color composition, color is not a product of perception but arises from the accumulation of repeated acts of measurement.

#### 3.1 Quantum Color Mixing

By mixing measurement results obtained from multiple quantum circuits in arbitrary proportions and performing quantum state tomography on the resulting probability distribution, mixed states can be obtained in which multiple quantum states are probabilistically blended, along with the mixed colors that emerge from them. In such mixed states, the qubit state collapses into the interior of the Bloch sphere, and the purity of the color is reduced.

#### 3.2 Color-Mixing Experiment Based on Quantum Color Theory

Mixing the colors of the two qubits on the left and right produces the color of the central bar. On the Bloch sphere, this corresponds to the point located at the midpoint between the two original colors.

- Quantum Mixing No.1 251128
- Quantum Mixing No.2 251216
- Quantum Mixing No.3 251216

- Quantum Mixing No.4 251216

## 4 Colors of Quantum Entanglement

In quantum color theory, hue is defined as relative, since the global phase of a qubit does not affect measurement outcomes. Color does not arise as an intrinsic property of an individual entity, but emerges from structures of relation and interference. To articulate this, controlled rotation (CRZ) gates are used to generate “relations between colors,” or correlation phases. A CRZ gate applies a rotation by an angle  $\theta$  around the Z axis to the target qubit only when the control qubit is in the  $|1\rangle$  state, thereby embedding the rotation angle as a nonlocal correlation shared between the two qubits.

As the brightness of the qubits increases, the influence of entanglement becomes stronger. As the rotation angle of the CRZ gate increases, color increasingly belongs to the relationship between qubits rather than to individual qubits; local colors fluctuate, and their saturation gradually decreases. When the rotation angle reaches  $\pi$  ( $180^\circ$ ), entanglement becomes maximal. Colors obtained after applying a CRZ gate are therefore not attributes of single qubits, but relational colors that emerge through measurement.

When the density matrix of two entangled qubits with nonlocal correlations is estimated via full quantum state tomography, three types of color representations are obtained: “Local HSV,” corresponding to individual qubit states; “Coherence HSV,” representing correlations of identity; and “Parity HSV,” representing correlations of contrast. In each case, hue corresponds to the orientation of the correlation encoded by the CRZ gate, saturation to the strength of the correlation, and brightness to the probability weight occupied by each correlation.

### 4.1 Colors Emerging from Quantum Entanglement

- Quantum Color Entanglement No.1 251125:  
Two qubits initially in the  $|0\rangle$  state are first subjected to RY (Y-axis rotation) gates, then entangled using a CRZ (controlled Z-axis rotation) gate, and their colors are measured through partial quantum state tomography. From left to right, the qubits are rotated about the Y axis by  $30^\circ$ ,  $60^\circ$ ,  $90^\circ$ ,  $120^\circ$ , and  $150^\circ$ . From top to bottom, the rotation angle of the CRZ gate is set to  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ ,  $180^\circ$ ,  $225^\circ$ ,  $270^\circ$ ,  $315^\circ$ , and  $360^\circ$ .
- Quantum Color Entanglement No.2 251216:  
Two qubits initially in the  $|0\rangle$  state are first subjected to RY gates, then the target qubit is flipped with a Z gate. The qubits are subsequently entangled using a CRZ

gate, and their colors are measured through partial quantum state tomography. From left to right, the qubits are rotated about the Y axis by  $30^\circ$ ,  $60^\circ$ ,  $90^\circ$ ,  $120^\circ$ , and  $150^\circ$ . From top to bottom, the rotation angle of the CRZ gate is set to  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ ,  $180^\circ$ ,  $225^\circ$ ,  $270^\circ$ ,  $315^\circ$ , and  $360^\circ$ .

- Colors of Quantum Entanglement 251118 / 1125 / 1223:

Two qubits initially in the  $|0\rangle$  state are first subjected to RY gates, then entangled using a CRZ gate, and four colors are generated through full quantum state tomography. From left to right, the rotation angles of the RY gates are set to  $[60^\circ, 60^\circ]$ ,  $[60^\circ, 120^\circ]$ ,  $[90^\circ, 90^\circ]$ ,  $[120^\circ, 60^\circ]$ , and  $[120^\circ, 120^\circ]$ . From top to bottom, the rotation angle of the CRZ gate is set to  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ ,  $180^\circ$ ,  $225^\circ$ ,  $270^\circ$ , and  $315^\circ$ . The paired elements at the center left and right correspond to the Local HSV representing the individual qubit states. Above them is the Coherence HSV, representing correlations of identity, and below them is the Parity HSV, representing correlations of contrast. In this image, the saturation and brightness of the Coherence HSV and Parity HSV are normalized.

The rotation angle of the CRZ gate is distributed across the hues of the Coherence HSV and Parity HSV. When the Bloch vectors of the two qubits have the same sign with respect to the Z axis, the brightness of the Coherence HSV increases; when they have opposite signs, the brightness of the Parity HSV increases.

## 5 Quantum Rainbow Flags

The six colors that constitute the rainbow flag are mapped onto six qubits in a quantum circuit. Two colors are then selected, and their phase difference is used as the rotation angle of a CRZ gate to entangle them quantum-mechanically, thereby generating a new color. By employing two different topologies and, in each case, reversing the roles of the control and target qubits, four distinct patterns of flags are generated from nine pairs of qubits.

The rainbow flag, which celebrates diverse ways of living, has long symbolized a world in which each individual existence is equally respected. Through quantum color theory, this symbolic palette is connected to the quantum domain, renewing the way its meanings are understood. Prior to measurement, qubits exist in an indeterminate state as “possible forms of life,” and quantum entanglement represents a relationship that remains connected across distance, preceding separation into individual entities. Rather than erasing difference, it affirms being together while holding difference.

This work is both an experiment using a quantum computer and a cultural practice. Just as color does not exist in isolation but acquires meaning through relationships with others, no category exists on its own; all exist in superposition and are entangled with one another.

The Quantum Rainbow Flags are hopeful color poems that gesture toward future forms of solidarity that bind across boundaries.

Table 1: Meanings of the Colors of the Rainbow Flag and Qubit States

| Color  | Meaning  | RGB            | HSV               | Phase $\varphi$ | $ r $ | $\theta$ |
|--------|----------|----------------|-------------------|-----------------|-------|----------|
| Red    | Life     | (195, 0, 1)    | (359°, 100%, 76%) | 359°            | 1     | 49/131°  |
| Orange | Healing  | (228, 140, 32) | (30°, 86%, 89%)   | 30°             | 0.86  | 63/117°  |
| Yellow | Sunlight | (249, 237, 55) | (52°, 78%, 98%)   | 52°             | 0.78  | 79/101°  |
| Green  | Nature   | (73, 128, 45)  | (107°, 65%, 50%)  | 107°            | 0.65  | 30/150°  |
| Blue   | Serenity | (44, 77, 252)  | (236°, 83%, 99%)  | 236°            | 0.83  | 82/98°   |
| Violet | Spirit   | (101, 1, 133)  | (284°, 99%, 52%)  | 284°            | 0.99  | 31/149°  |

- Original Quantum Rainbow Flag 260106
- Entangled Rainbow Flag No.1, Topology A [2, 9, 6, 7, 4, 5, 8, 3, 1] 251202
- Entangled Rainbow Flag No.2, Topology B [1, 9, 2, 6, 5, 3, 4, 7, 8] 251202
- Entangled Rainbow Flag No.3, Topology A (Inverted) [8, 1, 6, 3, 5, 9, 4, 2, 7] 251202
- Entangled Rainbow Flag No.4, Topology B (Inverted) [7, 8, 5, 3, 2, 4, 1, 9, 6] 251202