NER: Physical-Virtual Multimodal Generative NFT with a Rarity Model

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Abstract

Nowadays, NFTs are increasingly emerging into public view. It is necessary to consider NFT as a sustainable trading model for media arts with audience interaction as the symbiosis community.

This article presents a design architecture of a Multimodal NFT with generative patterns triggered by sensors. By designing various 3D mesh attributes, such as eye patterns and fur colors of a robin bird, the authors generate a series of different NFT 3D artworks. We also demonstrate our experience with the generative system together with the rarity scoring model that could be used to evaluate the heterogeneity of NFT collections.

Keywords

Multimodal NFT, Generative Art, Sensor-Driven, Self-tracking Data, Rarity.

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Introduction

As new “digital titles (tokens) to property, either real or virtual, stored on a blockchain” [12], Non-Fungible Token (or NFT) influences various social aspects, such as financial markets and art collections, especially media art creation. We believe that apart from its commercial exploitation, NFT represents a new medium that gives artists a different way of thinking about the creative process.

Multimodal interaction [3], i.e., “interaction with the virtual and physical environments through natural modes of communication”, has been a widely accepted term in media art creation. It, however, seldom appears in the NFT artwork creation.

Computational Generative Art (CG-art) is defined as the art “produced by leaving a computer program to run by it-self” [2]. By manipulating the generative design process, various artists have produced different captivating generative artworks over the years. In connection with NFT, new methods of displaying artworks have recently evolved, both online and offline, in addition to the computer screen and physical print presentations.

Guo et al. state “the art world will witness a new form of art economy with the coming of Web 3.0 (the metaverse), benefiting from its augmented creativity and sophisticated marketplace.” [7]. This article provides a short review of Generative NFTs, multimodal dynamic NFTs, and physically mixed virtual NFTs with different NFT rarity models. We then demonstrate our experiment NER, which creates a Multimodal Generative NFT with sensors and a rarity model.

Related Work

Multimodal Generative NFTs Commercial online NFT collection platforms, such as OpenSea [15] and SuperRare [24], are usually non-customizable. Recent advances in computational generative art have renewed interest in generative art in different materials [27]. Artists and researchers have generated various 2D patterns. For example, Zhang and Yu develop a font generation system in the style of Kandinsky [26]. Others attempted to create 2D generating textures on 3D mesh, such as Wu and Huang’s artwork “Mimicry” [25], which is a genetic-algorithm-based realtime system that creates virtual insects within a real environment. These generative artworks are not changed into NFT format due to technical limitations. At the same time, a NFT art collection platform, especially for generative art, called ArtBlocks [23] pushes the limits of generative art with blockchain technology. There are many interesting generative artworks on this website, especially in the category of curated collections.

Digital artist Pak built a generative NFT artwork “Merge” [13] which returns a new mechanism with collectors. Merge obtains the number of each collector during the 48-hour sale and generates dynamic on-chain NFT based on the total mass number. The NFT visual becomes bigger when collectors acquire more mass. This NFT artwork builds a new way that collectors can be seen as an entangleable and competitive symbiosis community. Refik Anadol studio used projection mapping on the facade of Casa Batllo´ to model the dynamic NFT artwork “Living Architecture” [9] with weather sensor data collected in realtime. This dynamic NFT renews and reinvigorates World Heritage building through AI technology. Most NFT artworks containing physical and virtual versions are highly relevant to commercial applications, particularly brand marketing. For example, Nike, together with RTFKT, established a range of virtual sneakers and expanded into physical goods, such as clothing. Look Labs [10] uses near infrared spectroscopy to create a digital scent, and translate the scent into NFT artworks, making it the world’s first digital fragrance [17].

NFT Rarity NFT rarity shows how rare a NFT item is compared to the rest of the items from the same collection, which in turn can represent how valuable such a collectible can be. When looking at a collectible NFT item on Opensea, such as a CryptoPunk [6] , one can see that the item has many traits, for example, accessories like an earring, a bandana, or a pipe. Since each NFT item has multiple traits, several rarity calculating models exist to combine each trait’s rarity into a single value per NFT item to rank and compare different NFT items.

Mainstream rarity calculating tools that can calculate and compare NFTs, such as Rarity.Tools [20] , offer four models for users to calculate the rarity of NFTs: Trait Rarity, Average Trait Rarity, Statistical Rarity, and Rarity Score (see Figure 1).

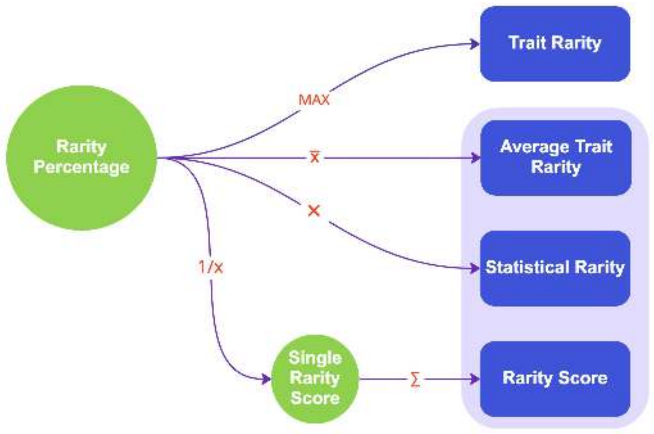

Figure 1: Four rarity models ©Authors

The Trait Rarity model works by only comparing the rarest trait of each NFT item. While it is a simple, straightforward model, this model's weakness is also apparent. It does not consider the total number of traits or other traits of the NFT item. As a result, this model provides an incomplete picture of the NFT item, ignoring other traits that may also be rare.

The Average Trait Rarity model [19] averages the rarity of traits that exist on an NFT. This model adds up the rarities of all traits and divides the result by the total number of traits to obtain a score representing the entire NFT item. Although this model takes the overall rarity of the traits into account, it "dilutes" the rarity values of those traits that might be extremely rare.

The Statistical Rarity model multiplies the rarity percentages of all traits to calculate the overall rarity of an NFT. However, this model does not measure the NFT's rarity in the specified collection of the NFT. If there are two two-trait NFT items, one with a rarest trait and a least rare trait, the other with two somewhat rare traits, then this model gives the latter a higher rarity value.

The Rarity Score model [18] is developed by the founder of Rarity.Tool. The model first takes the inverse of the rarity percentage of each trait as the rarity score of every single trait. Then the model adds up each rarity score calculated previously as the overall rarity score for the entire NFT item. This model not only considers all the traits of a single NFT item, but also measures the NFT's rarity in the specified collection. We, therefore, use this model in our work to calculate the rarity score.

NER Creation Process

Our NFT creation, called NER (NFT-Enabled Robin) , combines a real-world furry toy with a digitally generative 3D model (see Figure 2).

Figure 2: Physical and Virtual Bird appearance ©Authors

The following subsections provide details of the design process: (1) Converting a physical bird into a virtual bird via NFT. (2) Designing a virtual NFT trait and its rarity model. (3) Dynamically generating cloth in response to the change of mobile sensor data.

Physical and Virtual Birds with NFC

Figure 3 shows the workflow for transforming a physical bird to a virtual bird NFT. First, we store a physical NFC card in a small bag on the back of each physical bird (see Figure 2). Then we enter different redemption codes into different NFC cards to ensure every code is unique and hard to replace. Second, NER collectors can obtain the redemption code by tapping their phones with an NFC card and entering our app to paste the code (see the left image of Figure 4). Our server receives the signal from the user and directly detects the user's internet status to ensure each redemption code to be redeemed only once. If the user's phone does not connect to the internet, the NER app displays a warning (see the middle image of Figure 4). If the user's phone is connected, the NER app shows a shaking egg (see the right image of Figure 4). Third, our server checks the status of each redemption code; if the code is the 1st time redeemed, the NER app generates a unique virtual bird NFT; if the code is already redeemed, our app directly displays the existing NFT.

Virtual NFT trait design with a rarity model

A virtual NFT artwork can be divided into two parts: 3D mesh rendering with a rarity model, and 2D patterns generated by Shader with multimodal sensors which will be discussed in the next subsection.

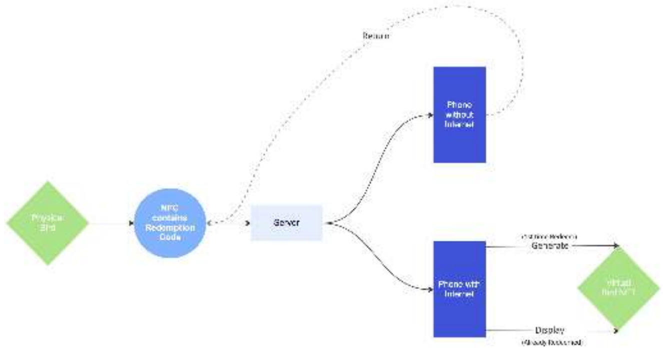

Figure 3: Transformation workflow of physical bird and virtual bird with NFC, Server and Phone ©Authors

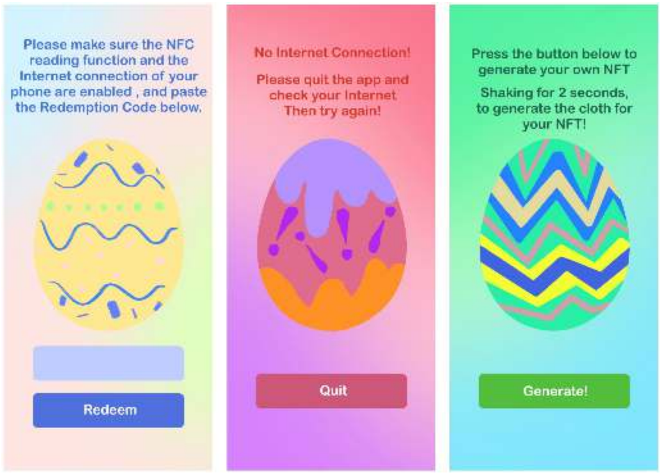

Figure 4: Three types of user interface ©Authors

Our design architecture considers different parts of virtual traits from top down (See Figure 5).

- Hairstyle.
- HairColor.
- EyesPattern.
- BeakColor.
- FeetColor.
- BackgroundColor.

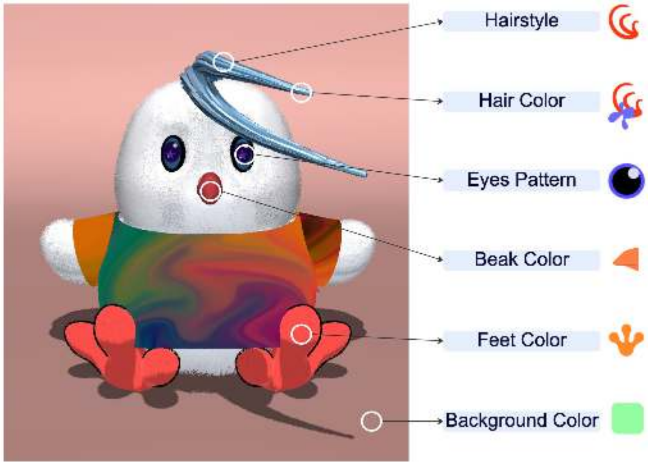

Figure 5: Virtual bird design with 6 traits ©Authors

Both the beak color and feet color have two variations. The one with a higher rarity among all the variations holds the rarity percentage of 30%, and the other holds the rarity percentage of 70%. Hairstyles have three different trait variations. Ranking from the rarest hairstyle to the most common one, the percentages of owning them are 15%, 30%, 55%, respectively. For those traits (hair color, eyes pattern, background color) with four variations, we define their rarity percentages, from low to high, as 10%, 20%, 35%, 35%, respectively (See Figure 6). With these six traits, NER has 768 variations in total.

Trait	Variation	Rarity Percentage	Rarity Score
Beak Color		30%	1/30% = 3.3
		70%	1/70% = 1.4
Feet Color		30%	1/30% = 3.3
		70%	1/70% = 1.4
Hairstyle		15%	1/15% = 6.7
		30%	1/30% = 3.3
		55%	1/55% = 1.8
Hair Color		10%	1/10% = 10
		20%	1/20% = 5
		35%	1/35% = 2.9
		35%	1/35% = 2.9
Eyes Pattern		10%	1/10% = 10
		20%	1/20% = 5
		35%	1/35% = 2.9
		35%	1/35% = 2.9
Background Color		10%	1/10% = 10
		20%	1/20% = 5
		35%	1/35% = 2.9
		35%	1/35% = 2.9

Figure 6: NFT bird trait's Variation, Rarity Percentage and Rarity Score ©Authors

To illustrate how to apply the above Rarity Score Model to calculate the rarity score for our NFT item, we choose a bird to represent the appearance (see the 4th image of Figure 8). This bird has a hairstyle with the rarity percentage of 15%, a hair color with the rarity percentage of 10%, an eyes pattern with the rarity percentage of 35%, a beak color with the rarity percentage of 30%, a background color with the rarity percentage of 35%, and the feet color with the rarity percentage of 70%. The single rarity score of each trait can be calculated by taking the inverse of that trait. For example, the single rarity score of its hairstyle is 1/15% ≈ 6.67. Using this method, 15% one may calculate the individual trait scores of all the traits and sum the results up to obtain the total score of this NFT item:

$$Total\ trait\ score = \sum^{All\ traits} Single\ trait\ score$$

$$= \frac{1}{15\%} + \frac{1}{10\%} + \frac{1}{35\%} + \frac{1}{30\%} + \frac{1}{35\%} + \frac{1}{70\%} \approx 27.1$$

Dynamically generating cloth

To generate the 2D cloth texture, we use multimodal sensors to obtain mobile self-tracking data to drive the generation.

As McLuhan stated in the book *Understanding Media: The Extensions of Man* [11], the opinions of media are the extensions of human, and reflected in all aspects of life in the digital era. Among different media, "mobile technologies have become an important part of our lives as they are capable of representing an extension of our physical selves" [8]. Thus, we use the user's mobile data to represent part of his/her self-portrait [16] in the virtual world.

To protect the privacy of our users, NER does not read and track personal data from their phones. Instead, it receives four types of data that affect 4 parts of the generation. Figure 7 shows the four types of data (i.e., three axes of gyroscope data and acceleration data) and the corresponding four aspects of the generation (i.e., the red, green, and blue channels of the visual pattern and its change speed).

Specifically, we receive two primary data types from the phone: gyroscope and acceleration. The gyroscope data influences color, while acceleration data influences the texture moving speed. More specifically, gyroscopes X, Y, and Z controls red, green, and blue colors respectively.

Figure 8 shows a series of generated results with rarity scores by different users.

Technical Implementation

The model of the NFT Bird is built with different pieces of 3D modeling software. The models of the bird and a series of hairs are created in Zbrush and Maya is used to modify and add UV maps to them. The fabric model is created using Marvelous Designer. After preparing the model and UV maps for the NFT bird, we use Substance Painter to paint a range of basic colors and apply different materials to the model. The model is then sent to Unity for the next stage of work: rendering and generation. In order to generate our Multimodal NFT with different mobile sensors, we developed a mobile application in Unity that contains three phases of operations: (1) Redemption: users can enter their redemption codes for generating the NFT. (2) Generation: users generate NFTs with their mobile sensors. (3) Saving: the user data of the generated NFT is stored for future review.

Redemption

In this phase, users must sign up and log in with their email addresses, and then enter a valid redemption code (see the left image of Figure 4) to ensure that the virtual NFTs generated are exclusively linked to their accounts. To verify whether a user has the chance to generate a virtual NFT, we produce 1000 unique redemption codes and store each of them in an NFC card placed in the bag of each physical NFT bird. A redemption code consists of 10 characters, including digital numbers and both uppercase and lowercase letters, with over 8×1017 distinct combinations. We store all redemption codes on the server and keep track of their states. Whenever a redemption code is used, its state is changed from 'Unused' to 'Redeemed' to ensure that each redemption code can only be redeemed once to generate one virtual NFT bird. A used code is stored under the account which has applied the redemption so that the specific account can review the NFT generated with the code.

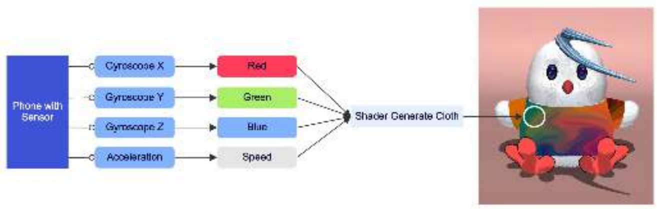

Figure 7: The mapping relationship between the sensor data and visual elements generated by Shader ©Authors

Generation

The generation phase begins right after the user enters a valid and unused redemption code in the Redemption Phase. In this phase, NER first lets users personalize the shader for the cloth of the virtual NFT birds, and then randomly decides the traits for the user according to the rarity percentage of the traits.

Shader Personalization

The shader we use for the cloth of the virtual NFT is inspired by a shader "70s Melt" [1] written in OpenGL Shading Language (GLSL) in an online shader community, Shadertoy [21]. Based on GLSL, we develop our shader in High-Level Shader Language (HLSL) acceptable by Unity. We add to this shader four properties, that can be set by the data gathered from the sensors. The first three properties drive the personalization of the color, determining how much red, green, and blue are applied in the shader, respectively. The last property controls how fast the pattern on the shader changes. We use the gyroscope sensor to set the first three properties related to the color. A gyroscope sensor can measure the angular velocity of the device. As shown in Figure 9, we define the axis parallel to the long side of the phone screen as the x-axis, the axis parallel to the short side of the screen as the y-axis, and the axis perpendicular to the screen as the z-axis. The device rotation around the x, y, z-axis determines the amount of red, green, and blue of the shader respectively. For the last property related to the moving and changing speed of the pattern, we use the accelerometer sensor to control its value. The speed is positively related to the magnitude value of the acceleration. The faster the device moves, the bigger the value is. To let users personalize the shader with their mobile sensors, our instructions in the Generation Phase (see the right image of Figure 4) tell users to shake their phones for two seconds to allow sensors to gather data.

Trait Generation

After the user has personalized the cloth, NER randomly determines what trait variations the NFT has based on the trait rarity percentage. For example, the trait rarity percentage of the hairstyle of the NFT in Figure 5 is 15%. If the system randomly generates a floating-point number from 0 to 1, only a value between 0 to 0.15 determines that the NFT can have this hairstyle. Other values correspond to other hairstyle variations.

Saving

The Saving Phase starts once the generation of the NFT is done. In this phase, all data related to the shader properties and the trait generation from the previous phase is written in a JSON file and stored on the server in the logged-in account. If the user of this account enters an already redeemed code again in the

Redemption Phase, all the stored data is fetched to directly display the generated NFT to the user, skipping the Generation Phase.

Conclusions and Future Work

First, the article reviews existing Multimodal Generative NFTs artworks and existing NFT Rarity models.

Next, we present a design architecture for creating a physical-virtual Multimodal NFT with generative patterns and rarity scores, called NER (NFT-Enabled Robin). It contains

– Transformation methods from a physical furry toy to virtual NFT generation with an NFC card;

– A 3D Virtual NFT system with different traits and rarity scores;

– Dynamic 2D patterns on a 3D mesh that changes in response to mobile sensor data.

Our NER is able to collect all traits and sensor data. These data can be sent to the NFT platform in real time to use We-bGL to convert existing data into the blockchain.

Figure 8: Samples of NER (NFT-Enabled Robin) generated by different users with rarity scores ©Authors

Future Work

In the future, we plan to establish a NER NFT collector community as a symbiosis ecosystem. The vitality and longevity of NFT artworks are highly related to their own community of collectors. Good NFT communities usually contain users' spontaneous secondary creations, like CryptoKitties [5] and SpaceDAO [22]. We may organize offline human-computer interactive workshops to let NER collectors bring their physical birds with accessories and enable them to build different accessories and animations online.

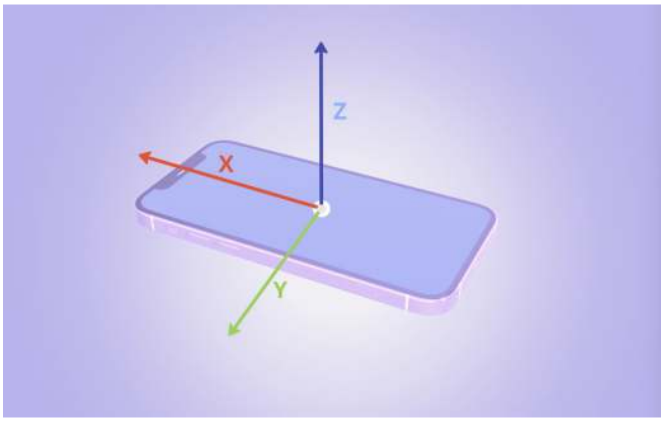

Figure 9: The mapping relationship between the gyroscope's axes and the phone ©Authors

We also wish to record the virtual birds generated by users and send them to a metaverse platform as unique digital assets to maintain users' emotional connection.

As mentioned earlier, the first version of NER has 768 variations. This is because it is convenient for the factory to make the physical bird toys and more controlled distribution for first-time NFT collectors. We expect the later version of NER to increase the number of traits and the number of physical birds.

The authors believe that "NFTs can be integrated with physical assets, properties, securities and insurance, thereby promoting diversified applications in art markets" [7]. Generative art and AI art, such as ChatGPT [4] and Midjourney [14], will play a significant role in future NFTs and their visual aesthetics and artistic values will be continuously improving. More details of our work can be viewed in the supplementary video at https://we.tl/t-x2G7ksWbDJ, that demonstrates to a clear method of creativity to our collectors and inspire other creators.

References

1 70s melt, https://www.shadertoy.com/view/XsX3zl.

2 M. A. Boden, E. A. Edmonds, What is generative art? *Digital Creativity* 20(1-2), 2009, 21–46.

3 M.-L Bourguet, Designing and prototyping multimodal commands, In *Interact*, volume 3, 2003, 717–720.

4 Chatgpt, https://chat.openai.com/.

5 Cryptokitties official website, https://www.cryptokitties.co/.

6 Cryptopunks - collection, https://opensea.io/collection/cryptopunk.

7 Y. Guo, Q. Liu, J. Chen, W. Xue, H. Jensen, F. Rosas, J. Shaw, X. Wu, J. Zhang, J. Xu, Pathway to future symbiotic creativity, 2022, *arXiv preprint arXiv:2209.02388.*

8 J. Harkin, *Mobilisation: The growing public interest in mobile technology,* Demos, 2003.

9 Living architecture by refik anadol, https://www.casabatllo.es/en/mapping/.

10 looklabs, https://www.looklabs.com/.

11 M. McLuhan, *Understanding media: The extensions of man,* MIT press, 1994.

12 A. Mekacher, A. Bracci, M. Nadini, M. Martino, L. Alessandretti, L. M. Aiello, A. Baronchelli, Heterogeneous rarity patterns drive price dynamics in nft collections. *Scientific reports* 12(1), 2022, 1–9.

13 Merge by pak official website, https://www.niftygateway.com/collections/pakmerge.

14 Midjourney, https://www.midjourney.com/.

15 Opensea official website, https://opensea.io/.

16 S. Park, Multimodal data portrait for representing mobile phone use behavior, In *Proceedings of the 25th International Symposium on Electronic Art (ISEA)*, 2019, 36–43.

17 J. Parkes, Look labs creates "world's first digital fragrance" as nft, 2021, https://www.dezeen.com/2021/04/08/look-labs-digital-fragrance-nft/.

18 Rarity tools explained: A guide to ranking rare nfts, https://nftnow.com/guides/rarity-tools-explained-a-guide-to-ranking-rare-nfts/.

19 Rarity tools explained, https://nftnow.com/guides/rarity-tools-explained-a-guide-to-ranking-rare-nfts/.

20 rarity.tools, https://rarity.tools/.

21 Shadertoy beta, https://www.shadertoy.com/.

22 Spacedao official website, https://thespace.game/.

23 Artblocks official website, https://www.artblocks.io/.

24 Superrare official website, https://superrare.com/.

25 Z. Wu, and L. Huang, Mimicry: Genetic-algorithm-based real-time system of virtual insects in a living environment-a new and altered nature, *Proceedings of the ACM on Computer Graphics and Interactive Techniques* 4(2), 2021, 1–8.

26 K. Zhang, J. Yu, The computer-based generation of fonts in the style of kandinsky. *Leonardo* 54(4), 2021, 437–443.

27 K. Zhang, S. Harrell, X. Ji, Computational aesthetics: on the complexity of computer-generated paintings, *Leonardo* 45(3), 2012, 243–248.

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Ziwei Wu is a media artist and researcher who was born in Shenzhen. She is a Ph.D. student in Computational Media and Arts (CMA) at HKUST. Her artworks are mainly based on biology, science, and the influence on society by using a range of media. She is a Lumen prize winner; Batsford prize winner. Her research was published in the SIGGRAPH Art Program and EVA London. She has exhibited at international venues, including CYFEST in Southeastern Europe, Norwegian BioArt Arena (NOBA)-Vitenparken in Norwegian, Watermans Gallery and Cello Factory in London, NeurIPS AI Art Gallery, ArtMachine2 in Run Run Shaw Creative Media Centre in Hong Kong and so on.

Danlu Fei is a game developer and researcher. She owns a bachelor degree in Computer Science - Computer game. She worked as a gameplay programmer intern at several well-known game companies, including Ubisoft, Behaviour Interactive, and Netease. She is pursuing her Ph.D degree in Computational Media and Arts (CMA) at HKUST. Her research interest is mainly around procedural content generation (PCG) in games, especially AI-based PCG. Her research was published in the CHI Play conference proceedings.

Xinyu MA is an art practitioner residing in Shenzhen and Hangzhou, who holds a bachelor's degree in sculpture and a master's in fine arts. Currently, he is pursuing a master of philosophy degree at the Hong Kong University of Science and Technology (Guangzhou). His work focuses on experimenting with various forms of public system structures, investigating their modes of operation in an individual, fictional, and fictitious way. In addition, he also researches the topics of the public sphere, philosophy of technology, urban space, community, play, and political aesthetics.

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