Self && Self

A Joint Senior Project Submitted to
The Division of Science, Math, & Computing and The Division of the Arts

by
Shuang Cai

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Dedication

To Po po and Gong gong

(And Mom and Dad of course)
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1 Introduction

Seldom before the COVID-19 pandemic have so many people simultaneously had their lifestyle drastically changed in the same way. The forced physical isolation is, ironically, a communal experience. The sickening quarantine left everyone nothing but time to confront and reconnect with themselves. Another inevitable result of corporal isolation is the predominant awakening awareness of digital existences and connections. Evoking the shared sensitivity and delicacy, studying the tectonic activity of the digital world, the project documents the endured contemplation in the upcoming resurgence.

1.1 Technical Establishment

The project - *Self & Self* - is a clustering of bridges, connecting the physical and digital dimensions, enabled by computational image processing and stereo vision technology. Installed by the entry hall of the Fisher Studio Arts Building - a transitional space, the show is constructed by five components: *The Invitation, The Surveillance Screens* with non-functional ceramic cameras, *The Emergence Dance* video series, *The Conversation* on Zoom, and *The Pointcloud Interaction*. All the technical tools will be further explained in *The Show* segments. Both the digital and physical invitations *mirror* the invitees in spirits of self-reflection. The digital invitations are created using
p5.js while the physical invitations are on individual laser-cut mirrors and pieces of glass. Accomplished by Processing, the *Surveillance Screens* pointing towards the audience illustrate a self-reflection process for each individual. In response to the extension on the surveillance discourse, the ceramics cameras mockingly attempt to reconcile the human-camera relationship. The *Emergence Dance*, the *Conversation*, and the pointcloud *Interaction* are a further extension of the linkage between physical materiality and its digital integration.
2 Concepts

2.1 The Self Observation - Out-of-body Experience

Among the strangest things that happened during the pandemic, the harrowing self-observation should be bestowed with a prize. When the familiar but particular face appears once again on the tenth selfie shot today, the mirror in the bathroom that has been gazed at for way too long, and a Zoom meeting’s unconsciously pinned window, one may start to ponder how exhausting but prepossessing self-observation actions are. Indeed, countless erstwhile philosophers, artists, and scientists have contemplated the topic of self-observation. A heartfelt investigation made by William Preyer (1995)—a German physiologist—documented his son’s early regime and shed a spotlight on the boy’s “articulation” of self, as a whole chapter is dedicated to “DEVELOPMENT OF THE FEELING OF SELF, THE "I"-FEELING” (p. 190). Preyer marked a baffling moment of the boy attempting to find another person behind the mirror at week fifty-seven and the boy’s playful act of making a face at himself at week sixty-nine (p. 198). In the observation journal, the father gleaned from the son’s vivacious daily changes, seeking for the watershed moment of his son’s self-recognition because that instant will be the milestone of an individual sifting themself out of the all-encompassing world, initiating the timeless confrontation between self vs. other, and, hence, subjectivity vs. objectivity.
Preyer’s study on his son’s self-recognition signifies the importance of confrontation between subjectivity and objectivity.

In *Self & Self*, the awareness of self is construed as an out-of-body experience. Figuratively, the observation one makes of oneself could be construed as a duplication of the self. At the moment of observation, subject and object simultaneously exist as separate entities. The co-existing individual who scrutinizes themself and their duplicated self concoct the out-of-body experience.

Two of the ways to practice such out-of-body processes are a) viewing oneself in a mirror, b) viewing oneself from the third-person. With the same conceptual core, the two have divergent effects on people. When looking into the mirror, the direct appraisal is usually made upon the physical self. On the other hand, observing from a third-person point of view, the focus is, then, shed on the duplicated self. The perceptions, however, are malleable in our minds. For instance, looking at a supermarket surveillance camera above your head is uncanny for various reasons, so it is common to throw a couple of looks at it (See Figure 1). However, this time, you notice that there is a bald spot in the middle of your luscious hair. At that moment, the paean to your beauty suddenly vanishes, and you initiate touching your head tentatively to find the spot shown in the camera. Originally, you find the reflection of yourself quizzical and enchanting. Then, your bald spot discovery shifts your focus from the
camera-captured self to your material self. Intrigued by the nuanced distinction and connection between the forms of out-of-body experience, I embarked on the journey of gleaning reproducible out-of-body encounters for the viewers.

Figure 1. Supermarket Inspirations (Author’s Photo, 2021)
2.2 Self vs. Other - Surveillance

In *The Phenomenology of Spirit*, George Wilhelm Friedrich Hegel (2018) explains the recognition of Self-consciousness by saying:

Self-consciousness is in and for itself while and as a result of its being in and for itself for an other; i.e., it is only as a recognized being. The concept of its unity in its doubling, of infinity realizing itself in self-consciousness, is that of a multi-sided and multi-meaning intertwining, such that, on the one hand, the moments within this intertwining must be strictly kept apart from each other, and on the other hand, they must also be taken and cognized at the same time as not distinguished, or they must be always taken and cognized in their opposed meanings... The elaboration of the concept of this spiritual unity in its doubling presents us with the movement of recognizing (p. 108).

The significance of the duplication of self mentioned in the previous chapter can refer to Hegel's explanation for self-consciousness. The very duplication process of self enabled the recognition of the original “self.” For moments of duplication, the separated self exists as an “other” to the original self. The emergence of the “other” in the observation renders the process greatly resembling surveillance. While the self-observation happens on a daily basis, we seem to be holding a grudge against being observed by others for various reasons: the invasion of privacy, the limitation of actions, etc. However, I am more concerned with why the participation of the other would
create these intuitional aversions—the difference between self and other. Presenting the self-observation process through the lens of surveillance, my project challenges the border separating self and other, which then leads to our opposing attitudes toward self-observation and surveillance.

Another factor that separates surveillance from the discussed self-observation is the deprived exchange of emotions. In 2010 at MoMA, Marina Abramović engaged in a performance called, *The Artist Is Present* (See Figure 2). In the performance, she sat at a wooden table across from a chair, silently waiting as viewers took turns sitting in the chair and allowing their eyes to bore into each other. Over the course of the

Figure 2. Performance Gallery View, Marina Abramović’s *The Artist Is Present*, 2010 (https://www.moma.org/calendar/exhibitions/964?installation_image_index=123)
performance, having no control over the staring duration, she exchanged endured gazes with multitudinous viewers, many of whom were brought to tears. Abramović and the viewer shared a similar demonstrative experience of observation, inasmuch it shares the delicacy of a self-observation. Having little control over the exchanged experience, Abramović managed to create sensitive and emotional but exact moments for the viewers. The self-observation process often possesses this level of sensitivity as we are constantly interacting and relating with the duplicated self.

Another reason why our self-observation mirrors Abramovic’s performance is because the roles of observer and observee are fluid and interchanging in both processes. This embodies Hegel’s claim that the reflectiveness of self-consciousness is autopoietic. Surveillance, on the other hand, strips off such interaction between participants. Both parties’ emotions ferment separately even if both are informed about each other (not to say surveillance sometimes does not occur in secret). This crucial distinction between surveillance and self-observation renders one of the absurdities in *Self & Self*. 
2.3 The Questioned Digital Existence

Figure 3. Exhibit view, Bruce Nauman, *Nature Morte*, 2020

Bruce Nauman’s *Nature Morte* (2020) employs many stereo vision technologies. In the piece, he makes public his private studio workspace by using the 3-D camera captures with three viewing stations. Then, the three 3-D captures from different perspectives of the studio are mapped into three 2-D renderings and projected on the wall. The virtual camera of the space is controlled by viewers via iPad controllers (See Figure 3). Viewers also have the liberty to view any object in the space at closeup in any desired way since Nauman scanned all the objects with a hand-held 3-D scanner. The
specificity of the 3-D models generates great mobility for viewers’ navigation experience. While Nauman translated physical matters to media, his presences are subtly gleaned and delineated by the “glitches” in the studio model. The gaps between unconnected faces and the scrunched renderings are the ramification of Nauman’s movement in the space. With this piece, the artist has made a step toward a radically digitized metaphysical existence. In his practice, he managed to perform the digitalization process on himself and leaves plenty of space for the viewers to fabricate his physical existence. In my project, the physical aspects are rooted in the viewers themselves because the project reflects upon the viewers and only exists if someone is looking at it. The project leaves viewers no liberty to imagine their physical existence but forms a codependent relationship with them.

The codependency between my show and the viewers is parallel to our relationship with the digital world. With the visuals becoming more augmented, the acoustics improving day by day, digital technology has its finesse to coax us into believing that it is capable of creating an intact perfect replication of the world. It is often overlooked that we are the Creator of the digital world, and we are famous for imperfection.
However, the digital world could be totally imaginable. It could be considered a different universe from ours, just as how Bruce Nauman employs the glitches to seize his existence in the digital in *Nature Morte*. If the visual of the glitches are to appear in the actual world, no individual will see them as Nauman’s existence. For another example, the color red in informatic form could just be a vector, \((255, 0, 0)\), but depending on the shades and the conversion method (RGB vs. HSV, etc), it could also be a completely different vector or snippet of code. Therefore, treating digital existence solely as a reflection of the actual world is extremely limited.

![Figure 4. The Loop of Digital Existence, (Author's Image, 2021)](image)
We use information to represent our interpretations of reality, locating the otherwise concealed digitalized world, creating a brand-new perspective to fathom the tectonic structure of the digital, and hence, the actual world. In the digital world, the tectonic plates could be the binary code and its compiler and interpreter, or the physical motherboard that carries the CPU, RAM and ROM chips, etc. Regardless of the way the digital world is deconstructed, the foundations of the digital world should also be studied expecting dynamics and fluidity like the movement Alfred Wegener proposed in *The Origin of Continents and Oceans* in 1992 about tectonic plates. As a programmer, a digital geologist and architect, I see endless potential—not only artistic but philosophical—in the codependence between the digital and us. Instead of aiming for perfect replication of the world and trying to debug it when it does come close to replication, I wish to understand and interpret our relationships with the digital world. This is because relying on computers to have such an objective, autonomous perspective on human existence is both creating issues in which we badly affect technology, such as AI with human biases, and in which technology harms us, such as the social damages and isolation resulting from media algorithms. Therefore, questioning the digital existence is a means to break the vicious cycle of unhealthy codependency and step towards a healthier alternative.
3 Journaling Process

![Figure 5. Left: a sketch in early planning stage; Right: the show in construction (Author’s Photo, 2021)](image)

Before reenacting the curated experience for the viewers, I had the voyage on the topic of my own subjectivity. Over the past couple of years, a consistent theme of my works included creating a Quasi-Pseudo self: self-portraits that extend beyond a sole reflection and exist as their own character. While some echo my physical appearance, others look nothing like me. Hence, "Quasi-Pseudo" is appropriate because it captures the absolute “fakeness” and etherealness of the duplication of self.

While I occasionally used to denounce this as a narcissistic act, extending the Quasi-Pseudo self to the viewers in my senior project has vindicated the journey. As a rationale for the peregrination of my self-observation, *Self & Self* injects my humor and pathos in the hope to share the experience with others.
3.1 Quasi-Pseudo Digitized Myself

Quarantine at Bard College started in March 2020. In professor Dave McKenzie’s class: ART 250 Extended Media II, I created Quarantine, the game, a collection of self-referential pseudo-memes disguised as a survival game (See Figure 6). Counter-intuitively, when some people feel distressed about the situation they find themselves in, they tend to do things that would make them even more distressed. Yet this practice could be proven to be therapeutic. In this piece one sees this Chelsea-Esque cyber-being engage in a series of routine/not-so-routine chores, spanning from eating, pooping, etc., to going crazy sporadically. In a way, this piece is a collection of diary entries that I have kept during this special time of our lives. It is highly private, intimate; it is also unapologetically open and blunt. So much so that it gets packed up and turned into a computer game, one-click, and $19.99 away for anyone who’d be willing to give it a try - in fact, the last part is actually a prank I’m trying to pull off: the one with the Steam shop on the top of Figure 6 is bogus, courtesy of the very real, omnipotent Adobe Creative Suite. Quarantine, the game is my first attempt to digitize my existence with a visual representation, which eventually led to my work in Self & Self.
Figure 6. Quarantine, the Game  (Author’s Image, 2020)
3.2 Notes on Hands

I have an obsession with the ends of my limbs: hands and feet being the furthest from the “body,” detached from the main body by nature. While looking at mirrors or selfie cameras requires the aid of an external device, looking at the ends of limbs is one of the most direct representations of disassociation and self-observation.

Way before quarantine, I have thought about the very topic of creating a Quasi-Pseudo self. I created the fictional figure, Cornelius, from a red striped sock in July 2017 as a substitute for myself (See Figure 7). Respectfully, its Instagram page was made to publicize its persona to the world. The post rationalization for the active choice of using a sock pointing to the detachment nature of limbs end. Cornelius’ ongoing life begins from an early subtle wish for my escape into the metaphysical world. Now is patently too early to end it.

Figure 7. Cornelius’ Birth Photo (Author’s Photo, 2017)
In October 2020, the beginning stage of preparing for my senior project, I documented the products of an observation I made on myself. While I was observing the subject - my hand - I was also the observer. I scanned my left hand multiple times in the library with different poses, and documented the process (See Figure 8). Hand gestures, being an extremely political subject, sometimes take the shine away from the concept of disassociation. However, the complexity of hands makes the observation even more intriguing and worth noting. Here are some excerpts from the process:

“I saw my left hand on the left, on the right, on its palm, as a fist, relaxed, flexed. 
It was me.
I put my left hand on the left, on the right, on its palm, as a fist, relaxed, flexed.”

Figure 8. One of the photos from my observations on hands (Author’s Image, 2020)
Building on top of the artistic approaches based on my obsession with hands, after taking CMSC 352 Machine Learning with Professor Sven Anderson at the end of 2020, I made an attempt to explore the intersection between computer science and my philosophical interest in the topic of hands. *Reading Hands* is a hand-gestures recognition machine learning project. The project creates a base model, then allows the users to enter their data of series of hand images to retrain and tailor the model to their purposes.

The project uses Convolutional Neural Networks (CNNs) from TensorFlow (https://www.tensorflow.org/)—an open-source library for machine learning. The base model in the project contains a data augmentation layer, three convolutional 2D layers, a max-pooling layer for each convolutional layer, and an output layer with three units. The input layer is sized (120, 320, 1). The (120, 320) are the dimensions for the frame, and the third dimension indicates the images are read as grayscale. In one of the convolutional layers, a “same” padding is used to deal with frames of the edges. Instead of using a designed complete architecture such as resnet50, the project is designed to have a small simple architecture that is beneficial when it comes to the customization for the individual users, for a small model can then be fully re-trained to fit the specific user and their environment. Normally, we do not want to retrain the entire model with a large dataset when retraining. In *Reading Hands*, the retraining can happen on the
whole model thanks to its small size, and more crucially we designed the base model to later be specialized on the users’ aspect of the gesture recognition problem.

The result shows that the base model can perform well with the given training environment and specific trainers. Using the data dependency characteristics of the convolutional neural network, the base model can be trained to specialize in any situation on this problem with light retraining. *Reading Hands* uses the data-dependent characteristic of convolutional neural networks and approaches a simple problem on hand gestures recognition. For future attempts, the model obtained from this project can be used on a real-time hand gesture recognition project. It is efficient and easy for the model to classify one singular frame. Feeding a frame of a real-time stream into the model every other 0.3 seconds should be sufficient for human eyes to consider the result as real-time. Figure 9 is a collage made with the Google Collab interface.
Figure 9. Collage Made on Reading Hands (Author’s Image, 2020)
3.2 Mirrors and Projectors

Another aspect of Self & Self is the bridging between mirrors and digital images. With mirrors being the most rudimentary form of self-duplication, my wish to build a nexus between cameras/projectors and mirrors started with an utilitarian goal.

In the summer of 2019, I was in Bard Summer Research Institute (BSRI) team that used the feed from a wide-angle camera on a mobile scribbler robot to create an immersive environment in a medium-sized cardboard geodesic dome using a spherical mirror and a projector (See Figure 10). The goal of the project is to provide an inexpensive, easy-to-use, configurable immersive robot interface for things like drones in more humble settings than places like large museum planetarium installations.

Figure 10. Simplified Graph of the Projection Environment (BSRI, 2019)
In the dome project, the robot is controlled wirelessly using an OSC interface which supports live-coding, and the video is warped using an idealized spherical mirror optimization. Because we used a round dome surface and a spherical mirror to display a wide angle feed, the image has to go through two distortion matrices in order to be accurately projected on the dome. The first distortion matrix flats out the wide-angle image onto a plane. The second distortion matrix distorts the image so that the right things are displayed at the right spot on the dome for the human eyes. We used plane-estimation in OpenCV (https://opencv.org/), a real-time optimized Computer Vision library, to find the distortion matrices to accomplish the task.

Figure 11. Calibration Plane in the Wide-angle Camera and Post Distortion
Left is the original feed from the wide-angle camera; right is the post-distortion images from the forward calibration matrix.
(BSRI, 2019)
4 The Show

4.1 The Title and Overview

Figure 12. Sketch of the installation (Author’s Drawing, 2021)

Having pondered on ideas such as Autopoiesis, The Out-of-Body Experience, The In Project, etc, I did not title the show until the very last minute before the vinyl had to be printed. The final title: Self && Self is a one-line code poem summarizing the show in which the two booleans - Self - are joined together with the logic gate AND. The code Self && Self can be eventually rendered to just a single Self because the two
booleans are the same one. The process of writing and interpreting the code literally recreates the process of self duplication and recognition. There is no practical meaning to join two identical booleans with an AND logic gate but a concise reflection on the purpose of this project: eventually, the sole existence of Self is determinant.

Figure 13. The Gallery Lobby Floor Plan with Surveillance Cameras’ Detailed Layout (Author’s Drawing Based on the Floor Plan of Fisher Studio Art Building, 2021)

As shown in Figure 13, the Surveillance Screens’ wall is facing outwards to a glass door. Being connected to the space outside, the show is captivating people passing outdoors but also forcing the experience onto people who are just passing through the lobby.
4.2 The Invitation

Composed of two parts, physical and digital, the invitation is “mirroring” the project with its self-reflection effect created for the viewer (See Figure 14).

4.2.1 Physical Invitation

The physical invitations are a mixture of mirrors and glass pieces with the letters laser-cut on the surface. For both kinds of physical invitations, the viewers could either opt to read the text or stare at the reflection of themselves. The mirror invitation symbolizes the focused self-reflection and obsession. The inherent transparency of glass emblematizes the self-less trance beyond self-presence reached by the persisted contemplation of self-observation. The laser-cut engravings text are realized by Glowforge Pro 3D Laser Printer, in font New Courier—a fixed-width font.

Figure 14. The physical Invitations, Left: Mirror, Right: Glass (Author’s Photo, 2021)
4.2.2 Digital Invitation

The digital invitations are hyperlinked on my artist website - www.Shuang64.com (See Figure 15). Upon opening the invitation, the viewers will see a pop-up window requesting permission for camera access. Clicking “Allow”, the viewers then see themselves on the invitation, opposite in direction from their usual mirror reflections. Overlaying the reflections floats a 3D text box containing the show information, rotating. Clicking on the text box will stop the rotation and display the readable content in green with font New Courier consistent to the physical invitations. Formulated with uncanniness and awkwardness, the digital invitation sends a subtle reminder about the unbounded potential of the digital world beyond a sole reflection of material reality.
The link is built by p5.js (https://p5js.org/) - a creative coding JavaScript library. Then, it is published on a GitHub repository. Having started my coding journey with learning in Processing (the powerful creative coding sketchbook that Bard uses for its introductory coding class; details about Processing will be explained in 4.3), I chose p5.js since it is such a salubrious tool for me considering it adapts the core principles of Processing. On top of that, I chose the p5.js library for the following reasons:

1. It is easy for me to visualize the invitation using the visual library;

2. p5.js’ HTML adaptability allows me to transmit the invitations efficiently via websites, creating great accessibility for the invitees;

3. The WEBGL mode in p5.js easily allows 3D-rendering by introducing the third dimension, Z for all the location parameters, which eventually allows the spinning 3D text box to emphasize the tangibility of the digital world;
4.3 The Cameras

4.3.1 Surveillance Screens

Figure 16. Top: Gallery View; Bottom: Viewer in the space with Surveillance screen
Top Left screen Clockwise- Cam 1, 2, 3, 4 (Author’s Photo, 2021)
Capturing viewers’ self-observation action, four surveillance screens are displaying camera feeds that are shooting viewers standing in front of the mirror and the screens from behind (See Figure 16). While the mirror reflection is dedicated to the direct duplication of self-consciousness, the viewers are looking at themselves in the surveillance camera resulting in the emergence of the third removed perspective. On the opposite side of the main wall of the surveillance screens, there is an identical large rectangular mirror at the end of the stairs coming down from the second floor. Standing in front of that additional mirror, the viewer will have a full view of the setup on the main wall while observing themselves looking at the setup through the mirror. Figure 17 is taken from the additional mirror.
With four cameras surrounding the viewer facing to a mirror point outwards. Beyond the idea of the duplication of self, each of them serves a different purpose. All of them are achieved by Processing (https://processing.org/). Camera 2 and Camera 3 are connected to two Raspberry Pi computers. The other two are hosted on regular laptops and bonded on the stairs. Figure 18 shows how the hardware and software cooperate to represent and embody the final result.
Camera 1 is a direct feed, shooting down from the second floor of the gallery space. As the supermarket surveillance camera example mentioned in 2.1, the autonomous perspective of camera 1 is an absorbing reminder of how malleable our focuses on the doubled selves are. Processing’s `Capture.list()` returns a list of all available capture devices which makes it possible to use the extruded webcam as the streaming device for the screen.
Camera 2 passes the video feed to color processing by switching the order of the regular color processing mechanism - (R, G, B) - to (B, G, R) (See Figure 19). Camera 3’s video feed goes through rasterized image processing in which each pixels’ blue value is sifted out and mapped on a scale of 50 to 150 to determine the size of the square (See Figure 20). The processed video has a bizarre and otherworldly tone while directly reflecting the viewer’s back and their face in the mirror. The uncanny and disassociating effect emphasizes the capability of the digital world. Camera 4 displays the pixels’ (R, G, B) value directly instead of a perceivable image. Adopting the classic-matrix look, Camera 4 is visualizing how information is stored and interpreted by computers (See Figure 21).
Algorithm-wise, the pseudocode for the rasterization process in Camera 3 is:

1. Determine a **base** for tile size (I used the blueness of the central pixel)
2. For each row in the heights (increments by tile size)
   a. For each column in the width (increments by tile size)
      i. Get the **blue value** of that pixel;
      ii. Map the **blue value** (originally between 0 and 255) on a scale of 0 to 1 as a weight to time on the **base**;
      iii. Draw a square at that location with a side length of **base** times the mapped **blue value**;

Figure 20. Camera 3 Screen, Gallery View (Author’s Photo, 2021)
Similarly, Camera 2 and Camera 4 follow the same logic to access each pixel required for a legible visualization. In Camera 2, the incrementation for the two for-loops is 1, since every pixel must be adjusted. In Camera 4, the incrementation for the rows is 80 in order to display the entire sequence of numbers and not interfere with the adjacent one. The maximum length for each color vector is 72 - each number is 8 pixels long in width and the maximum length is 9 numbers. For the same reason, the incrementation for the column is 10 - the height of numbers.
For Camera 2, 3, and 4, the built-in `pixels[]` array in Processing are called for direct access of pixel information. The array `pixels[]` contains the (R, G, B) values for all the pixels in the display window in a series of 24 bits. In other words, the (R, G, B) value for each pixel looks like RRRRRRRRGGGGGGGGBBBBBBBB where R stands for red, G stands for green, and B stands for blue. For example, if the top-left-corner pixel is a pure white dot, that pixel’s (R, G, B) values are stored in `pixels[0]` as `0b11111111 11111111 11111111` which translates to 255 255 255 in decimal. I used the right shift operator- `>>`, Bitwise AND- `&`, and hex numbers expressing byte - `0xFF` to grab the desired information such as (R, G, B) values for Camera 2 and Camera 4, or blue values in Camera 3.
The Raspberry Pi computers are educational single-board computers (https://www.raspberrypi.org/). In the show Self & Self, two Raspberry Pi computers are incorporated in the show as an art piece because of the small and flexible appearance. The two Pi computers stand among the forest of ceramics cameras on tripods, having HDMI cords hanging from the ceiling mimicking vines. The physical establishment of the technical installation - the wires and the tripods - are kept in the space as a reminder of the digital world’s physical infrastructure (See Figure 22).
4.3.2 The Fake Cameras

There are twenty-four non-functional ceramics cameras displayed in the gallery space (See Figure 23). They are a playful snare for the viewers when they come close to the show to comb for the real cameras observing them. Unlike the average callous functional cameras that are normally black or silver, the fake cameras are covered with bright callow glazes. The fake cameras’ dimensions also range from normal camera/webcam size to miniature size hidden all over the space (See Figure 23).

Figure 23. Miniature Cameras Details, Gallery View  (Author’s Photo, 2021)
As a counter force pulling away from the intimidating black-and-silver enigmatic modern technology, ceramics serve as my ploy to lightening the mood with its archaic organicness. Meanwhile, the nature of the clay sculpting process left omnipresent human traces on the cameras, raising a question to the irrational trepidation towards the camera technology and the negligence on the human input in the process.

Figure 24. Part of the Fake Cameras Setup, Gallery View  (Author’s Photo, 2021)
4.4 The Emergence Dance

Figure 25. The Emergence Dance Series, Gallery View (Author’s Photo, 2021)

The piece Emergence Dance is a video collage self-portrait displayed in a corner of the gallery space. The video is compartmentalized into four quadrants, of which two are the digital self struggling to emerge from the abyss (bottom right and top left in Figure 25), and the others are the digital self materializing its existence by feeling its appearance (bottom left and top right in Figure 25).

I made the Emergence Dance footage with the Intel RealSense D435 — a stereo solution RGBD Camera — by cutting off the pixels from rendering on the screen at a fixed depth (detailed pseudocode is on page 45).
Unlike normal RGB cameras offering images as a matrix containing (Red, Green, Blue) information for each pixel, RealSense depth cameras offer depth information on top of the normal (R, G, B) information. Each pixel captured with the RealSense camera will have four attributes: (R, G, B, D) where the depth information, “D”, is determined by stereo vision.

Stereo vision solution is based on how real-life depth perception is generated - the binocular disparity between the images of an object in left and right eyes. By comparing information about a scene from two vantage points, the depth information can then be extracted by the geometrical relationship between the real-life point and the two points as shown in Figure 26.

![Figure 26. A Geometric Demonstration on Stereo Vision (Author’s Image, 2020)](image)

As the camera puts real-life three-dimensional objects into two-dimensional images, the process of converting from world to camera pixel coordinates is called projection. The projection process depends on a point in world coordinates and several
calibration parameters. These parameters only depend on the camera without components from the real world, therefore referred to as intrinsic calibration parameters (Dorodnicov et al, 2020):

\[ \text{Proj}(x, y, z) = F \cdot D_{\text{Model}} \left( \frac{x}{z}, \frac{y}{z} \right) + P \]

| \( (w,h) \) | Width and height of video stream in pixels |
|\hline|\hline|
| \( P=\left(p_x, p_y\right) \) | Principal Point, as a pixel, offset from the left edge |
|\hline|\hline|
| \( F=\left(f_x, f_y\right) \) | Focal Length in multiple of pixel size |
|\hline|\hline|
| Model | Lens Distortion Model |
|\hline|\hline|
| Coeffs=\(\left(k_1, k_2, k_3, k_4, k_5\right)\) | Lens Distortion Coefficients |

Table. 1 The Intrinsic Calibration Parameters

Extrinsic parameters are describing the translation and rotation between each pair of camera/projector, connecting each viewport with a translating vector \( t \) and a rotating matrix \( R \). The relationship between the world coordinates with respect to sensor A and the world coordinates with respect to sensor B can be presented through the matrix multiplication (Dorodnicov et al, 2020):

\[
\begin{pmatrix}
    x \\
    y \\
    z
\end{pmatrix}_B =
\begin{pmatrix}
    R & t
\end{pmatrix}
\begin{pmatrix}
    x \\
    y \\
    z
\end{pmatrix}_A
\]
The D435 model consists of a left imager (RGB camera), a right imager, and an infrared projector. The infrared projector projects a non-visible static IR pattern to improve depth accuracy in scenes with low texture. The left and right imagers capture the scene, and the two images are used in stereo vision to obtain a depth value for each pixel in the image. The depth pixel values are processed to generate a depth frame (“Intel RealSense D400 Series Product Family Datasheet,” 2020). The final output for the Intel RealSense camera is referred to as a pointcloud which will be further introduced in 4.5.

The code accomplished Emergence Dance is primarily built on one of the demonstrations offered by the Intel RealSense SDK2, rs-pointcloud.cpp. In rs-pointcloud.cpp, `draw_pointcloud()` is a function created in example.hpp, the helper library, that primarily calls to OpenGL which plots out the result pointcloud. The critical modification is made on the iteration that went over all the points in the pointcloud before feeding into OpenGL. Instead of loading all the points that have a Z coordinate data to OpenGL, I added an integer constraint for the z coordinate data making sure only the ones that are close to the camera at a certain plane will be rendered. The algorithm looks like:
1. Get all the vertices data and put them in an array `vertices[]`;

2. Get all the texture coordinates and put them in an array `tex_coords[]`;

3. For all the points
   a. If the vertex has a z coordinate that is less than 20
      i. Draw the vertex with OpenGL with its texture;

By cutting off the RGBD camera footage from a static depth, I am investigating the rudiments of cameras - rays of lights and angles. Understanding the principles of cameras and computational images, I was given the vocabulary to deconstruct the digital from its source. From the deconstruction, I visualized a symbolic emergence of the digital. The naming of the piece - *Emergence Dance* - signifies the poetic aspect of the logic behind the digital construction and draws an analogy between coding and choreography.

Figure 27. Detailed Shot of Emergence Dance  (Author’s Image, 2021)
4.5 The Conversation

![Figure 28. 1’26” in Conversation (Author’s Image, 2021)](image)

Conversation is a two-minutes materialized internal conversation I had with myself on the platform of Zoom. The script of the conversation is attached in Appendix II. As one of the college students graduating in the COVID-19 pandemic, I thought about it may seem futile to include any explanation about Zoom in my thesis project write-up. However, for future preservation purposes, Zoom is an online chat and meeting service that was vastly used throughout the pandemic. Zoom as the tool of the times carries out an impossible conversation bridging the digital and the physical.

As part of the narrative, at 49 seconds, the digital self on the top switched its form from a regular webcam with a blue textured background to a 3D pointcloud visual enabled by the Intel RealSense D435 Camera. In the video, the digital self rotates and
zooms the pointcloud to emphasize the difference between a plain digital image and a 3D pointcloud. A pointcloud is a dataset that represents objects or spaces in three dimensions. A pointcloud contains at least three dimensions to store information about the geometric coordinates of the physical objects. Any extra information such as the texture or color will be added to the pointcloud data as other dimensions. The composed matrix is then projected onto a plane such as the computer screen that is used for Conversation and Interaction. Pointcloud itself is a useful abstraction for visualisation, animation, model rendering, etc. In Self & Self, pointcloud is mostly used for a visualisation of camera-oriented concepts.
4.6 The Interaction

One of the most direct applications of RGBD cameras is enabling the interaction between the digital and the physical: having the corporeal movement reflect on the digital existence without the confinement of a physical interface such as keyboards or mice. The piece Interaction is the onset for the reconstruction of the relationship between the digital and the physical. While Emergence Dance and Conversation is a dedication to the digital world through the materialization of the digital me - the artist, the Interaction is a materialization for all the viewers. A live feed from Intel RealSense D435 is
displayed on a screen, capturing the entire gallery space and rendering the captures as a 3D pointcloud through Unity.

Unity Technologies is a cross-platform real-time engine. It was first announced and released in June 2005 at Apple Inc.’s Worldwide Developers Conference as an OS X-exclusive game engine (Takahashi, 2018). The primary programming language used in Unity is C#. Unity is used to create a believable space for the pointcloud to create the out-of-body experience for viewers.

In Interaction, as viewers approach the setup, a default blue cube would pop into the viewers’ sight (See Figure 29). The depth information of the square is determined by the central pixel’s depth information. When the viewer is away from the setup, the cube will float in the background determined by further objects. The approach of the viewers will obstruct a portion of the background, forming the empty holes as the shadow of the viewer. While any movement can greatly rattle the space, the glitchy effect created by the inherently unstable environmental lightings also portrays the chaotic digital aesthetics.
5 Future Work

It must be such a cliché to see a Bard scholar writing how there are numerous things they wish they could have done for their senior project. I am only reiterating the fact that the printed and bonded documents handed to the registrar before 5 PM on the due date is never the ultimate end to the project but simply a start, as Self & Self is a conversation buttressed by an envisioned future on the timeless topic. Therefore, there shall be infinite iterations and expansions on the very topic in the future.

As mentioned in 3.2 Notes on Hands, having experience with machine learning, I see the possibility for the project to be guided with the assistance of the powerful machine learning tools. The participation of machine learning algorithms enhances the interactive experience for the viewers and brings on a further discussion about the relationship between the digital and physical. From a technical aspect, as depth is now an easily documented and abstracted information for images, the model could be trained with the depth information to have higher prediction accuracy or have a model on certain three-dimensional movement.
From 3.2 Mirrors and Projectors, the dome project also indicated a possible direction for a more immersive development of Self & Self. Now in Self & Self, the dissociation and self duplication still require the viewers to be thinking about the concept of self-awareness. By accomplishing a more realistic and direct out-of-body experience for all the viewers, augmented reality or virtual reality application on the topic will fully strip out the deliberations from the experience. Then, the pure sensational experience created by the digital would be a more powerful and radical approach to deconstruct and reconstruct the digital world.

As the project mostly focused on digitalizing the physical, another direction for the project is to explore the possibility of materializing the digital. Daniel Rozin, an artist teaching at NYU Tisch Interactive Telecommunications Program¹, made the piece - Wooden Mirror (1999) that reflects with the extrusion of a matrix of wooden tiles through a hidden micro-video camera as shown in Figure 30. The piece blurs the boundary between digital and physical by reconstructing the digital existence of the viewer in a physical domain. In Self & Self, mirrors are taken literally as the original form of self-duplication, whereas the symbol of mirror could also be reviewed from a critical perspective in the same way as our digital existences are in the project.

¹ Where I will be going for my graduate school!
Figure 30. Daniel Rozin’s *Wooden Mirror*, Gallery View, 1999
(http://www.smoothware.com/danny/woodenmirrormuseum.jpg)
6 Limitations and Conclusion

It almost seems to be entitled and irresponsible to say that, as an artist, I did not create the project with the intention of solving the problem with self-observation and disassociation (out-of-body), surveillance and the gap between self and other, or the vicious cycle of human-technology relationship. After all, one may say that I am a programmer with the knowledge that could potentially make a difference in a tangible way and that it is a privilege to have the programming vocabulary. I am, however, making an argument about how the responsibility of the programmers should be carried among the public. There was a metaphorical moment where I saw people who crossed into the space without the intention of looking at the show dodging and running away from the cameras. Part of the conclusion of the show is that, at least, I am wishing for a future where the understanding, or lack thereof, of programming language is not used to dodge the blame for creating the vicious cycle and responsibility for fixing it.
Figure 31. Viewers’ Selfies from the Show  (Author’s Instagram Stories, 2021)
Autopoiesis is describing a system that creates itself. The show is autopoetic in many ways - from the concepts of self awareness to the establishment of the camera shooting the viewers looking at themselves being captured staring into mirrors. Ironically, the show only exists when someone steps into the space. The show is not creating more shows but endlessly creating selves.

Viewer.TakingSelfie(Self.TakingSelfie(Captured(SurveillanceLens))); //similarly absurd, Me.Concluding(Self.Concluding(Art.Birthed(Autopoiesis)));^2

Aside from all the philosophical epiphanies and programming progress I made in the process of creating the show, *Self & Self* is a good source to induce some laughter that lasts at least for a while.

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^2 The viewer was taking a selfie of themself taking a selfie that is captured from a surveillance lens; similarly absurd, I am writing a circuitous conclusion of an autopoietic loop that is birthed from an art exhibit.
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References


Appendix I: Code Snippets

// Digital Invitation Code
let capture;
let font;

function preload() {
    font = loadFont('Asset/Courier.otf');
}

function setup() {
    createCanvas(640, 480, WEBGL);
    capture = createCapture(VIDEO);
    capture.size(640, 480);
    capture.hide();
    noStroke();

    fill(0, 0, 255);
    textSize(20);
    textFont(font);
    textAlign(CENTER, CENTER);
}

function draw() {

    background(255);
    image(capture, -320, -240, 640, 480);
    // filter(INVERT);
    // image(capture, 0, -480, 640, 480);
    let date = "Apr.25th - Apr.30st"
    let loc = "Bard Fisher Studio Art Building Entrance Hall"
    let title = "Shuang Cai"

    if (mouseX > 320 && mouseY<200) {

push();
fill(0,0,0,90);
translate(100, -100, 60);
rotateY(PI);
box(textWidth(date)+30, 160, 10);
translate(0,-50,-20);
fill(0,255,0);
rotateY(PI);
text(date, 0,0);
text(loc,-105,-20,textWidth(date),150)
text(title,-110,30,textWidth(date),150)
}

} else{
    let time = millis();
push();
translate(100, -150, 100)
rotateX((time+mouseX) / 1000);
rotateZ((time+mouseY) / 1234);
rotateY(1)
fill(0,0,0,90);
translate(0,50,-10)
box(textWidth(date)+10, 150, 10)
fill(0,0,255)
translate(0,-50,15)
text(date, 10, 0);
text(loc,-110,-20,textWidth(date),150)
text(title,-110,30,textWidth(date),150)
fill(255,0,0);
translate(0,100,-30)
rotateX(PI);
text(date, 0, 0)
text(loc,-110,-20,textWidth(date),150)
text(title,-110,30,textWidth(date),150)
pop();
}
//Camera 1: Default webcam capture but using the additional camera

import processing.video.*;

Capture cam;

void setup() {
    size(640, 480);

    String[] cameras = Capture.list();

    if (cameras == null) {
        println("Failed to retrieve the list of available cameras, will try the default...");
        cam = new Capture(this, 640, 480);
    } else if (cameras.length == 0) {
        println("There are no cameras available for capture.");
        exit();
    } else {
        println("Available cameras:");
        printArray(cameras);
        cam = new Capture(this, cameras[1]);
        //using the extruded webcam instead of the default
        cam.start();
    }
}

void draw() {
    if (cam.available() == true) {
        cam.read();
    }
    image(cam, 0, 0, width, height);
}
//Camera 2: Color manipulation displaying (b,g,r)
...
void draw() {
    if (cam.available() == true) {
        cam.read();
    }
    loadPixels();

    for (int x = 0; x < width; x++) {
        // Loop through every pixel row
        for (int y = 0; y < height; y++) {
            // Use the formula to find the 1D location
            int loc = x + y * width;
            int r = (cam.pixels[loc] >> 16) & 0xFF;
            // Faster way of getting red(argb)
            int g = (cam.pixels[loc] >> 8) & 0xFF;
            int b = cam.pixels[loc] & 0xFF;
            color c = color(b, g, r);
            pixels[loc] = c;
        }
    }
    updatePixels();
}
// Camera 3: Rasterization
...void draw() {
  if (camA.available() == true) {
    camA.read();
  }
  background(0);
  int centerIndex = width/2 + height/2 * width;
  // getting the central index for the base size
  float m = camA.pixels[centerIndex] & 0xFF;
  float tilesX = map(m, 0, w, 10, 100);
  float tileSize = w / tilesX;
  for (int y = 0; y < h; y += tileSize) {
    for (int x = 0; x < w; x += tileSize) {
      int loc = x + y * width;
      int blue = camA.pixels[loc] & 0xFF;
      float b = map(blue, 0, 255, 0, 1);
      pushMatrix();
      translate(x, y);
      rect(0, 0, b * tileSize, b * tileSize);
      popMatrix();
    }
  }
}
//Camera 4 - Printed RGB Value on Display
...
void draw() {
    if (cam.available() == true) {
        cam.read();
    }
    background(0);
    fill(0, 255, 0);

    for (int x = 0; x < width; x = x + 80) {
        // Loop through every pixel row
        for (int y = 0; y < height; y = y + 10) {
            // Use the formula to find the 1D location
            int loc = x + y * width;
            int r = (cam.pixels[loc] >> 16) & 0xFF;
            // Faster way of getting red(cam.pixels[loc]) with bit shifting
            int g = (cam.pixels[loc] >> 8) & 0xFF;
            int b = cam.pixels[loc] & 0xFF;
            text(r, x, y);
            text(g, x + 24, y);
            text(b, x + 48, y);
        }
    }
}
```cpp
```
cpp code that is used for Emergence Dance
// Wait for the next set of frames from the camera
auto frames = pipe.wait_for_frames();
auto depth = frames.get_depth_frame();

// Generate the pointcloud and texture mappings
points = pc.calculate(depth);

auto color = frames.get_color_frame();

// Tell pointcloud object to map to this color frame
pc.map_to(color);

// Upload the color frame to OpenGL
app_state.tex.upload(color);
```

```
```cpp
draw_pointcloud(app, app_state, points);
```
```cpp```
```cpp
draw_pointcloud method in cpp code that is used for Emergence Dance

/* this segment actually prints the pointcloud */
auto vertices = points.get_vertices();          // get vertices
auto tex_coords = points.get_texture_coordinates(); // and texture coordinates
for (int i = 0; i < points.size(); i++)
{
    if (vertices[i].z < 10)
    {
        // upload the point and texture coordinates only for points we have depth data if they are close to the camera
        glVertex3fv(vertices[i]);
        glTexCoord2fv(tex_coords[i]);
    }
}
```
//In RsDevice.cs customize code for getting the central pixel depth information. Global Variable is used later in MoveAloneCentral.cs
...
public float CentrePixelDepthDistance;
...
private void WaitForFrames()
{
    while (!stopEvent.WaitOne(0))
    {
        using (var frames = m_pipeline.WaitForFrames())
        {
            using (var depthDist = frames.DepthFrame)
            {
                CentrePixelDepthDistance =
                    depthDist.GetDistance(depthDist.Width / 2, depthDist.Height / 2);
                //Debug.Log(CentrePixelDepthDistance);
                RaiseSampleEvent(frames);
            }
        }
    }
}
MoveAlongCentral.cs: Unity C# code that is attached to the cube’s Z location

using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Intel.RealSense;

public class MoveAlongCenter : MonoBehaviour
{
    public Vector3 depth;
    public float d;
    void Start()
    {
    }

    void Update()
    {
        d = GameObject.Find("RsDevice").GetComponent<RsDevice>().CentrePixelDepthDistance;
        depth = new Vector3(0.0f, 0.2f, d);
        transform.position = depth;
        //Debug.Log(d);
    }
}
Appendix II: The Script of *Conversation*

Scene 1

[Two people that look kind of alike are in a really weird and awkward Zoom meeting. A mouse icon is in the center of the bottom right corner of the screen. The list of participants shows that both of them are someone named Shuang Cai, and one of them is the host. One has a virtual background of some kind of blue textured paper. The other one is in a warm lighted room.]

Physical Self

[Awkwardly]
So sad we only have two minutes.

Digital Self

[Trying to surpass the awkwardness]
YUP, So let’s cut to the chase, Shuang Cai.

Physical Self

Fine. What are you?

Digital Self

How rude! Nah I’m messing with you. To make you understand this better, I am a virtual you. I exist the same way you exist. Not necessarily in the way you are looking at right now, my current form is like this just for you to feel more familiar.

Physical Self

Interesting. What is your true form?

Digital Self

I don’t have a “TRUE” form. I can deconstruct this a little bit for you though. But tell me, why this combination of com sci (Computer Science) and art?

Physical Self

Because of purity. Computer science is not a utilitarian tool for me. Don’t you find the eureka moments in these two disciplines extremely similar?

[Digital Self changed their display into a 3D pointcloud format.] Woah what happened there?
Digital Self
Ya...This is a point cloud. Now it may be clearer for you that I might as well be a matrix. Does that scare you?

Physical Self
OMG not at all. I wish I was a matrix. Humans suck. There is no way we can ever escape our stupid biased little head, but we are pretending to have an objective perspective constantly. It literally just brings us shit.

Digital Self
It is hard for me to understand, but I can only empathize. I hate to break it to you though. Being pure in the virtual world is not going to free you from this. I'm struggling with different things. Heck! As my birth mother and myself, you know this better than anyone. Just to start with, I am struggling with existing. I barely exist in so many ways. For now, I exist because you exist. Your brain is doing a crazy job here, understanding a bunch of numbers as a figure. Think about you two years ago, you probably won’t have any idea what I am talking about right now. Not to mention you created this. Give the future you and the future, in general, a little bit of credit.

Physical Self
You have a point there. I guess I will see you in the future.
Appendix III: Press Release and Artist Statement
Self-consciousness is in and for itself while and as a result of its being in and for itself for an other; i.e., it is only as a recognized being. The concept of its unity in its doubling, of infinity realizing itself in self-consciousness, is that of a multi-sided and multi-meaning intertwining, such that, on the one hand, the moments within this intertwining must be strictly kept apart from each other, and on the other hand, they must also be taken and cognized at the same time as not distinguished, or they must be always taken and cognized in their opposed meanings...The elaboration of the concept of this spiritual unity in its doubling presents us with the movement of recognizing.

- George Wilhelm Friedrich Hegel, *The Phenomenology of Spirit*

In my project, the awareness of self is construed as an out-of-body experience. Figuratively, the observation one makes of oneself could be construed as a duplication of the self. At the moment of observation, subject and object simultaneously exist as separate entities. The co-existing individual who scrutinizes themself and their duplicated self concoct the out-of-body experience.

Two of the ways to practice such out-of-body processes are a) viewing oneself in a mirror, b) viewing oneself from the third-person. With the same conceptual core, the two have divergent effects on people. When looking into the mirror, the direct appraisal is usually made upon the physical self. On the other hand, observing from a third-person point of view, the focus is, then, shed on the duplicated self. The perceptions, however, are malleable in our minds. For instance, looking at a supermarket surveillance camera above your head is uncanny for various reasons, so it is common to throw a couple of looks at it. However, this time, you noticed that there is a bald spot in the middle of your luscious hair. At that moment, the paean to your beauty suddenly vanishes, and you initiate touching your head tentatively to find the spot shown in the camera. Originally, you find the reflection of yourself quizzical and enchanting. Then, your bald spot discovery shifts your focus on the camera-captured-self to your material self. Intrigued by the nuanced distinction and connection between the forms of out-of-body experience, I embarked on the journey of gleaning reproducible out-of-body encounters for the viewers.

The significance of the duplication of self can be related to Hegel’s explanation for self-consciousness quoted at the beginning. The very duplication process of self enabled the recognition of the original “self”. For moments of duplication, the separated self exists as an “other” to the original self. The emergence of the “other” in the observation resembles surveillance, though in this case you are surviving yourself.

While the self-observation happens on a daily basis, we seem to be holding a grudge against being observed by others for various reasons: the invasion of privacy, the limitation of actions, etc. However, I am more concerned with why the participation of the other would create these

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intuitional aversions - the difference between self and other. Presenting the self-observation process through the lens of surveillance, my project challenges the border separating self and other, which then leads to our opposing attitudes toward self-observation and surveillance.

In *Self &Self*, the physical aspects are rooted in the viewers themselves because the project reflects upon the viewers and only exists if someone is looking at it. The project leaves viewers no liberty to imagine their physical existence but forms a codependent relationship with them. The codependency between my show and the viewers is a parallel to our relationship with the digital world. With visuals becoming more augmented, acoustics improving day by day, digital technology has the finesse to coax us into believing that it is capable of creating an intact perfect replication of the world. It is often overlooked that we are the Creator of the digital world, and we are famous for *imperfection*.

However, the digital world could be totally imaginable. It could be considered as a different universe to ours, just as how Bruce Nauman employs the glitches to seize his existence in the digital in *Nature Morte (2020)*. If the visual of the glitches are to appear in the actual world, no individual will see them as Nuaman’s existence. For another example, the color red in informatic form could just be a vector, (255,0,0), but depending on the shades and the conversion method (RGB vs. HSV etc), it could also be a completely different vector or snippet of code. Therefore, treating digital existence solely as a reflection of the actual world is extremely limited.

We utilize information to represent our interpretation of reality, locating the otherwise concealed digitalized world, creating a brand-new perspective to fathom the tectonic structure of the digital, and hence, the actual world. As a programmer, a digital architect, I see endless potential - not only artistic but philosophical - in the codependence between the digital and us. Instead of aiming for a perfect replication of the world and trying to debug it when it does come close to a replication, I wish to understand and interpret our relationships with the digital world. This is because relying on computers to have such an objective, autonomous perspective on human existence is both creating issues in which we badly affect technology, such as AI with human biases, and in which technology harms us, such as the social damages and isolation from media algorithms. Therefore, questioning the digital existence is a means to break the vicious cycle of unhealthy codependency and step towards a healthier alternative.

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Thank you for reading.

Shuang Cai
Apr. 24 – Apr. 30

Self && Self