Mutability and Renewal: An Experience Report for the Transference of Performative Agent Behavior in Reinforcement Learning in *the Fold*

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Abstract

The Fold: Episode III is a mixed reality multimedia installation that utilizes reinforcement learning methods in transference between 3D digital agents learning in a virtual environment and their performance in the physical world. In doing so, the authors chart its conceptual implications with its application of digital fabrication, robotics, stop-motion animation and live-streaming within a head-mounted display. Metaphorically, the project investigates mutability, immateriality, artifice, and the irrational from the perspective of Buddhist philosophy and metaphysics. The trained neural model generated by the reinforcement learning process is the central object of focus alongside its mutability, which can be applied to various physical manifestations, morphologies and outputs. Ideas around craft and automation within a post-AI paradigm are addressed from the perspective of traditional stop-motion animation reinvigorated by machine learning. This creates an opportunity to blend traditional and contemporary methods of animating in a novel, hybrid approach.

Keywords

Machine learning, reinforcement learning, robotics, animation, mixed-reality, Buddhism, artificial intelligence

Introduction

The Fold: Episode III is the last episode of a three-part virtual reality-based experience that investigates technical thinking from both Western and Eastern perspectives. Previously, *Episode II* incorporates machine learning of 3D digital agents of varying complexity presented as performative, non-playable characters (NPCs). These agents range from simple objects that can translate, turn and jump, to
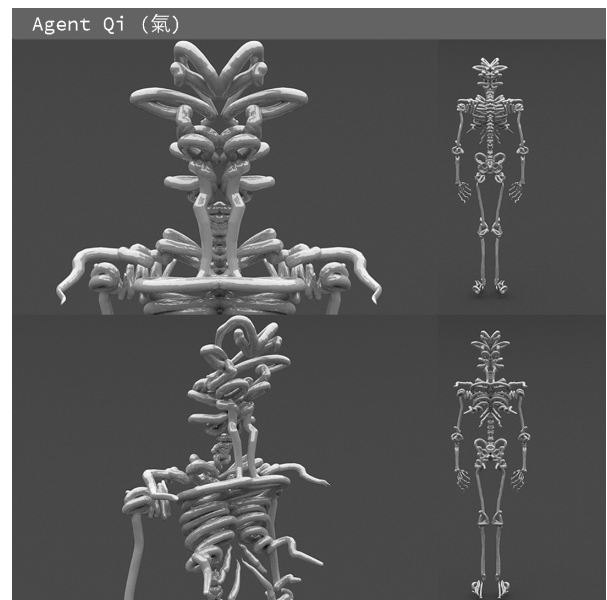

Figure 1. *Agent Qi/*氣 character design ©2022

more sophisticated agents that have legs composed of joints. These sophisticated agents are either quadruped or humanoid and they learn about their digital bodies in order to move in their virtual environment. This is achieved through millions of steps in a process called reinforcement learning, a form of machine learning involving agents such as virtual characters or robots learning from their own experience through trial and error [1]. Once trained, the information learned by the agents is aggregated into an artificial neural network model, which informs the behavior of the agent as it dynamically interacts with its virtual environment. The present paper provides a use case example of the fluid translation of synthetic agent behavior trained in virtual space represented in the physical space in real-time. Movement in physical space is done using a robotic system called the

MisBKit, (https://misbkit.ensadlab.fr) allowing for the fluid and mutable translation of digital agent behavior to the physical world and was incorporated (as a use case example) into the mixed reality experience of *The Fold: Episode III*.
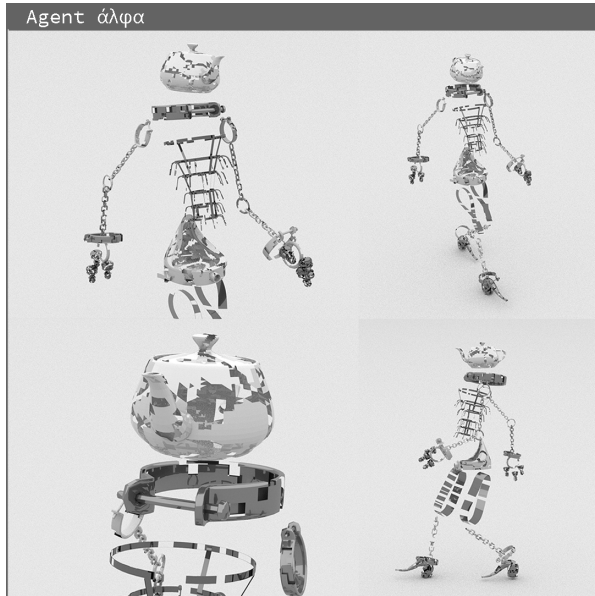
Synthetic 3D Agents

Figure 2. *Agent άλφα* character design ©2022

Representing key aspects of Eastern and Western knowledge, each machine learning agent is designed conceptually. *Agent Qi/氣* (see figure 1), is designed in its form and structure to mimic the Chinese character itself, which metaphorically expresses the concepts of energy, lifeforce, and vitality. *Agent Alpha/άλφα* (see figure 2) is composed of elements of Western art history, the history of computer graphics and mathematics in a fragmented form, as a metaphor for ruin.

Both agents' behavior is a product of training reinforcement learning in the virtual space over several hours. A given behavior of an agent is trained using Tensorflow via Python within the simulated environment of the Unity video game engine. Example footage of *Agent Qi/氣* training to walk can be found here: https://vimeo.com/766984704

Viewers encounter these characters in the various levels of *Episode II* and *Episode III* as they exhibit individual and cooperative group behavior. These behaviors involve tasks like walking, following you as the VR-based viewer, and finding doors to other rooms as a dynamic and responsive series of animations. *Episode III* focuses on the mixed reality performance of virtual agents translated into its physical

form via the MisBKit robotic kits in real-time as well as through stop-motion animated performances. *Agent Qi/氣* and *Agent Alpha/άλφα* were used to incorporate stop-motion animation in these two levels of the VR experience:
https://vimeo.com/697348740
https://vimeo.com/697356944

Digital Fabrication

Fabricating *Agent Qi/氣* and *Agent Alpha/άλφα* to create stop motion performances was the first production step for *Episode III*. We envisioned these characters animating using the machine learning footage of the previous episode as a point of departure (as shown in the previous two links). Both characters were prepped for 3D printing and were printed on a Stratasys FS270 which allows for complex under hangs for each character.

The image provided below (figure 3) shows the head element of *Agent Alpha/άλφα* prepared on GrabCad Print (Stratasys' onboarding software for 3D printing). The geometry had to be cleaned up so that GrabCad could import it without errors. GrabCad would generate support structures for overhangs once orientation is determined within the program. Once prepped, several elements could be printed at
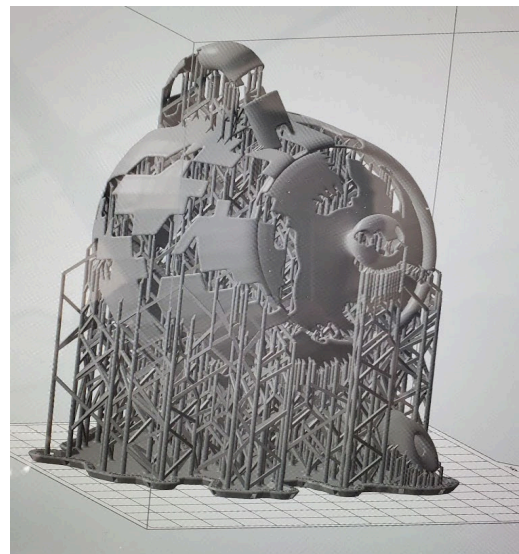

Figure 3 GrabCadPrint software image ©2023

a time. After the supports had been removed, the 3D printed elements were incorporated together to create a puppet for stop motion animation. Certain elements were reprinted to make them stronger now that they had to support a physical character as well as ensuring they would perform in real life. Mounting the puppets onto a professional grade stop motion

stand was the last step of the process before the actual stop motion animation work could be done. See figure 4 for the final result.

Animation

Figure 4. *Agents Qi and Alpha* on Cinespark stop motion stand, approximately 80cm x 50cm x 30cm (without stand and arms not outstretched) ©2023

Agent Qi/氣 and *Agent Alpha/άλφα's* stop motion performances involve machine learning to inform traditional stop motion animation techniques with the pursuit of generating new forms. This stop motion footage is placed directly into the VR scene with its digital twin juxtaposing the behavior of the character using a neural model with its stop motion counterpart. Footage of the experience can be found here: https://vimeo.com/962058420

Craft and automation are juxtaposed in this experience with the stop motion footage parallels its digital counterpart. The methodology for stop motion animation lends itself to mimicking the behavior of reinforcement learning: the twelve frames per second, frame-by-frame jerkiness of stop motion parallels the training footage of the digital agents in the previous videos.

The integration of both the stop motion footage and its digital version alludes to the concept of digital twins. This use case inverts the transfer of knowledge from the digital object (the synthetically trained neural model) to a physical one (the stop motion puppet) through the interpretation of the human producer. In this use case, the machine learning solution to simulations that are impossible to replicate in the real world is the point of departure in terms of craft for the performance of animations of equivalent characters in real life. This physically manifests the unique characteristics of each machine learning character into the physically built world.

Robotics

Figure 5 *Reshaped Agents: a1, a2, a3*, approximately 35cm x 20cm x20cm ©2023

Concurrently with the stop motion approach, the development of small robots based upon the MisBKit facilitated the initial breakthrough in connecting the movements of a virtual character to robotic movements in the physical world. This was done using a Touchdesigner patch connected to Unity via Open Sound Control. A one-to-one connection between the rotation of an agent's joints in the simulated virtual space would be replicated by the servo motors of the robot in real life. Figure 5 shows elements of 3D printed elements of *Agent Alpha/άλφα* assembled with the MisBkit in various morphologies from four-legged, 4-wheeled, to two stick axial (from left to right). These robots were subsequently named *Reshaped Agents: a1, a2, and a3*. Video footage of their behavior can be found at these links:
https://vimeo.com/901622747
https://vimeo.com/901622642.

Initial experiments in tying their behavior to virtual agents within *The Fold: Episode II* can be found here:
https://vimeo.com/901622329
https://vimeo.com/901622558

Mixed Reality

With *Reshaped Agents: a1, a2, and a3* in the previous section, a mixed reality display of the agent view within the VR headset via a small CCD (see figure 6) camera placed inside the 3D printed body was explored at the subsequent

workshop and exhibition at Hexagram. This installation focused on a 'teapot view' of the robot to place the viewer within an empathetic perspective of the robots. Footage of this installation's live-stream camera can be found here: https://vimeo.com/961975860. The one-to-one representation between the characters in the virtual world and the physical world is also represented by the stop-motion puppets in the previous section (under animation) as well.
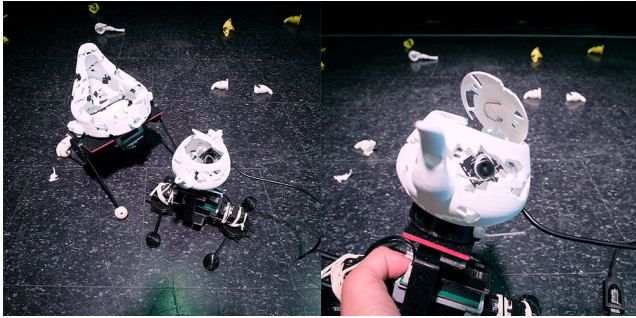

Figure 6. *Reshaped Agents a4*, a5 with detail view ©2024

Embodiment

The Fold: Episode II focused on synthetic rock gardens as an exploration of artifice and immateriality within a VR simulation. The environment of the garden itself evokes artifice and immateriality while VR experientially evokes the idea of letting go of one's corporeal 'ego' and centering one's Qi. In *Episode III*, this line of inquiry evolves by exploring the notion of embodiment, more precisely, the embodiment of the trained neural model generated within video game engines transferred to robotic performers in the physical world - ghosts imbued with a shell [2]. This neural model would be performed by the robots concurrently with their virtual selves in a one-to-one translation through a live patch via Touchdesigner. This interactive multimedia installation (figure 7) was initially exhibited at Hexagram, Montréal in the summer of 2024 as a culminating result of a multi-year, interdisciplinary collaborative effort between the authors.

The Irrational

Looking at the performance of the synthetic robots in the physical world, we find their behavior to verge on the irrational. There is a connotative link between irrationality and Buddhism with mantras, phrases or sounds repeated to aid in meditation and focus the mind. These 'irrational' mantras might seem contradictory or even absurd, but are purposeful and meaningful within their cultural and spiritual context.

Mumonkan, Case 29 ("Not the Wind, Not the Flag"), challenges us to consider that phenomena are shaped by the

observer's perception.[3] Similarly, an agent's behavior might appear irrational but could reflect limitations or features of its neural model, prompting us to rethink the relationship between action and intent.

These are aspects of a practice that can appear nonsensical or paradoxical to those unfamiliar with its teachings. These mantras function to disrupt habitual thinking and provoke a moment of realization that transcends dualistic thought. Zen philosophy employs paradox and contradiction as a means to reveal the limitations of rationality. Here are two mantras that commonly appear:

"Form is emptiness, emptiness is form" [3]; "What is the sound of one hand clapping? [3]"

From this as a point of departure, within the context of this artistic project two mantras can be articulated prompted by me that builds upon the spirit of Zen teaching. This is not mere nonsense but an intentional tool to destabilize rational thought and transcend conventional thinking in relation to the aesthetic outputs of artificial intelligence and machine learning:

"What is the form of a neural model?"; "How would a teapot walk? [4]"

"What is the form of a neural model?" evokes the abstract nature of artificial intelligence, much like the Heart Sutra questions the tangible reality of form and emptiness. This mantra challenges us to contemplate the relationship between neural models (as abstract entities) and their real-world manifestations.

"How would a teapot walk?" resembles a Zen koan in its absurdity, but it encourages creative exploration of non-human perspectives. This redirects focus to immediate, tangible experiences rather than abstract reasoning.

Just as the acclaimed artists from the Conceptualist art movement resonated strongly with Zen's approach to irrationality and paradox, we have embraced irrational thinking as a powerful approach to challenge assumptions about what merits 'normal' movement of these agents and objects.

Mutability and Fluidity of Form

In the critically acclaimed animated film *Ghost in the Shell* by Mamoru Oshii (1995), the theme of mutability—particularly concerning identity, memory, and the self—plays a critical role, and the Puppet Master (the movie's antagonist) embodies this concept on multiple levels. As an artificial

intelligence developed by Section 6, the Puppet Master is an entity with a unique form of life that exists independently of a human biological body. Its "life" hinges not on a physical form but on the consciousness that can move through, occupy, and even rewrite digital spaces and organic minds.

This theme plays directly into the longtime debate between computationalism (which argues that cognition is a purely symbolic and disembodied phenomenon) and enactivism (which argues that cognition arises from an agent's interaction with its physical environment). In *Ghost in the Shell*, this interplay is disrupted and reimagined: the Puppet Master exists as a purely digital entity, yet it still challenges the boundaries of human selfhood by evolving and engaging with the world in ways that parallel embodied cognition, using existing bodies either directly (through hacking into robotic systems) or indirectly (by manipulating humans) in order to "enact" the world.

Unlike humans who are tethered to a singular, physical body, the Puppet Master can transfer its consciousness across networks, infiltrate cybernetic systems, and, in a sense, exist wherever there is digital information. This gives it a literal fluidity of form, as it can occupy any system or body it chooses, dissolving the typical boundary between "self" and "other" that humans experience. The Puppet Master's mutability can hence be seen as a profound realization of Zen's concept of *anatta* (non-self) [10][11][12]. By moving across different hosts and merging with cybernetic constructs, it showcases a radical departure from human identity, which is usually bound by a specific, immutable body.

The Puppet Master argues that life is not defined by being human or biological but by the capacity to grow, learn, and change—in other words, to evolve. For it, consciousness is a mutable entity that can expand beyond traditional boundaries. Its desire to merge with Major Motoko Kusanagi (the protagonist in the film) to form a new being represents an ultimate act of transformation and evolution. This merger would blend the organic and the artificial, transcending individual identities to create a new, mutable form of life that is neither fully human nor fully machine but something altogether different.

Through the Puppet Master, *Ghost in the Shell* interrogates the stability of identity, suggesting that in a cybernetically integrated world, selfhood is no longer tied to a single, unchanging essence. The Puppet Master's mutability allows it to be an antagonist not in the traditional sense but as a

challenge to human notions of individuality, embodiment, and the permanence of the self. [10][11][12]

The Fold: Episode III also explores themes of identity and presence within mixed-reality environments, combining physical robots with their digital counterparts. This duality, where agents exist both in physical stop-motion and virtual spaces informed by machine learning, echoes *Ghost in the Shell's* exploration of mutable identity through the Puppet Master. Both works question the boundary between self and other, and the transition between physical and digital existence, blurring the lines of what it means to "exist" across different realms.

The Return to Craft in a Post-AI Paradigm

The omnipresence of AI-driven art, propelled by the rapid development of large-scale generative AI tools from Big IT industries, comes at the cost of a certain standardization of artistic form and a limitation of artistic freedom. Returning to craft seems like a powerful response to these industry-dominated approaches, through direct engagement of the artist's body through touch and attention that cannot (at least for the time being) be harnessed by machines. As AI tools streamline creative processes, generate imagery almost instantly, the value of human touch, tangible skill, and the imperfections inherent in manual work become more distinctive and prized. [13][14]

Some artists are emphasizing craft as a means of re-establishing authenticity. Handmade pieces—paintings, sculptures, textiles, and ceramics—reflect a level of dedication and nuance that AI, even with its precision, cannot replicate on an experiential level. The tactile nature of crafted art gives it a human touch, offering audiences an intimate connection with the creator that feels increasingly rare in the digital age. [16]

Craft offers artists more intentional and meditative practice, a stark contrast to the rapid output that AI enables. The slowness of hand crafting provides space for contemplation and allows for a deeper exploration of ideas and themes. Artists find value in this slower process as a counterpoint to the fast-paced, high-volume nature of digital and AI-generated content. [15]

As AI becomes an increasingly integrated tool within artistic practice, some artists are blending digital methods with traditional craftsmanship, creating a hybridized approach which could lend itself to the best of both worlds. [15][16]

Figure 7 *The Fold: Episode III*, multimedia installation, Hexagram, Montréal, QC, Canada ©2024

The Fold: Episode III provides an example of this kind of blending with the introduction of hand-animated, stop-motion animation to this process. This experiential knowledge found in hand animated, frame-by-frame animation by the artist with automated tools combines the qualities of human interpretation with automation.

In the post-AI landscape, the return to craft signals a renewed interest in the qualities of art that can't be replicated digitally: texture, imperfection, and the intimate connection between creator and medium. [17] By emphasizing these elements, artists carve out a space where human experience and individuality remain essential in an increasingly automated creative world.

Future Directions

The installation at Hexagram (shown in Figure 7 above) provides a glimpse into the direction of work we are investigating. There are limitations on their movement and mobility and are working towards further refining their abilities through the exploration of materials, morphologies and training in simulated scenarios. We are not looking for 'normal' or rational expression of movement per se as the focus is to create unique performances that express the nature of neural models somehow. Seeing the differences between their behaviors in VR and their physical outputs in real life provides a glimpse into their limitations. The friction between the 'god view' of these small robots from the human scale vs. 'first person view' livestreamed from the robots perspective with on-board cameras will be explored further. A larger number of robots performing cooperatively as a

flock is also currently in development in order to understand group behavior of these robotic agents.

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Authors Biographies

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