THE SILKWORM PROJECT

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The Silkworm Project is an installation series consisting of machine objects, experimentation and artifacts that explore the possibilities of hybrid bio-machine worlds that can generate self-organizing silk structures. The silk machines utilize a closed feedback system between the organic and the artificial, where the biological - in this case the silkworms, and the computational - the electronic and digital systems that provides a spinning environment for the worms, form one fluid eco-system demonstrating automated production that is autonomous in its nature. *The Silkworm Project* is a case study within a larger research interest and project by the artist that explores a non-human cybernetic systems approach to machine logic, specifically investigating the intelligence and ingenuity of insect.

The series is broken down into three parts. In the first part, *Machine I: Flat Spinning*, the artist takes a cultural and historical approach through the entangled history of weaving technology and computation technology, and places the silkworm and sericulture within a human-centric value system and machine system. The second part is centered around *Machine II: Spatial Spinning*, where the artist develops a machine logic that caters to the spatial perception of the silkworm and its spinning behavior, creating an artifact that brings out and projects the alien perspective of the biological insect. The third part speculates on a new animal/machine hybrid universe that is explored through the design of *Machine III: Levitation*. Through the process of exploration, the artist questions and speculates on the complex cultural, biological and technological fabric that makes up the context of the silkworm.

This series is a case study that investigates a larger research interest that I have been working on for the past few years with two main agendas. The first is an interest in cybernetic system and intelligent machine design, influenced largely by the British branch of cybernetic theorists and practitioners, the likes of Stafford Beer and Gordon Pask[1]. Humans have long explored the meaning and concept of life through technology, as early as the clockwork times of mechanical automatons. But what intrigues and inspires me in modern explorations, is the intervention of chaotic material and behavioral systems (chemical and biological) into a purely mechanical or machine system. This intervention introduces unpredictability into the traditional controlled environment of the machine, both complicating our understanding of the machine, and of life. The juxtaposition of the two begs for a new exploration of both definitions, and possibilities of new hybrid forms, relationships and perspectives between two otherwise traditionally competing logics.

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[1] Pickering, Andrew, The Cybernetic Brain: Sketches of Another Future. Chicago, London: The University of Chicago Press, 2010.

Second, I am interested in a bottom up, non-human, animal approach to intelligent systems design. Inspired by ideas presented by media theorist Jussi Parikka in *Insect Media*[2], and later by the works of researchers and authors such as Mike Hansell[3], and James L. Gould and Carol Grant Gould[4], I am fascinated with the intelligent behavior and creative potential of insects that exhibit building behavior. Besides the silkworm, I am also researching ants (fire ants and harvester ants) and bees. Rather than designing interfaces for humans, I position my work in the realm of animal interface design, where I draw from insights and methods deployed in behavioral biology and ecology to study the mechanisms of insect behavior and social structure, and these observations in tern then inform the concept, look and function of the installations.

Coming back to the silkworm series, many years ago, while researching the development and history of computers, I came upon the entangled history of weaving and computational technology. While the start of information technology was largely influenced by weaving, for the machines I were to create, I wanted to reverse this historical cross-over between technologies, and instead have electrical information influence the organization of silk, straight from the silkworm's mouth. In the early design of machine systems, exemplified by *Machine I: Flat Spinning*, my approach was mathematical and cartesian in its essence, referencing historical and present day artifacts such as the magnetic core memory, and different silkworm cocoon storage and spinning environments used in sericulture industries around the world. These designs placed the silkworm metaphorically and literally within a human-centered, industry-oriented frame of reference, where the silkworm is a commodity.

In 2012, I began raising silkworms every spring, devoting time to understanding their life cycle, bio clock and behaviors under different circumstances. This foundational study was very necessary for the design of the machine interface. The series aimed to generate non-cocoon-like silk structures through insect-machine interaction. In *Machine I: Flat Spinning*, I wanted to create flat silk structures, self-generated and uneven in density on a flat plane, almost like an embroidery, but organic and representative of the silkworm's own agency. However, this was easier said than done. I worked on creating an electro-stimulation grid to stimulate that provided both a spinning and stimulation environment for the insects. A camera overhead would capture the input of the silkworm's movement and position on the plane, and activate the electrodes to stimulate them to change positions. The silkworm acts as both the input and output of this system. However, the end result was this machine was not able to fully work. For one, although silkworms are able to respond to electro-stimulation due to having a nervous

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[2] Parikka, Jussi, Insect Media: An Archaeology of Animals and Technology. Minneapolis, London: University of Minnesota Press, 2010.

[3] Hansell, Mike, Built by Animals: The Natural History of Animal Architecture. New York: Oxford University Press, 2007.

[4] Gould, James L., Carol Grant Gould, Animal Architects: Building and the Evolution of Intelligence, New York: Basic Books, 2007.

system, I was unable to identify an ideal electrical range where a reaction could be triggered from the worms while not harming them to an extreme extent. Furthermore, spinning environment of the machine was to ideal and did not fit well into the reality of silkworm behavior during the spinning period.

In 2015, Neri Oxman and the Mediated Matter Group at MIT Media Lab published their work *Silk Pavilion*[5]. With this project, they proposed a new way of looking at digital fabrication through the lens of biomimicry, abandoning the additive method of DIY 3D printers, and directly printing an outward, encompassing structure in 3-dimensional space. This model was based on the silkworm's spinning behavior, where the team conducted numerous spatial experiments and tests on spinning silkworms in attempt to understand their method and how spatial restraints and variations can affect the final spun outcome. This provided me with a new way of looking at the spinning behavior. I adjusted my approach from designing with the silkworm to designing for the silkworm. Different from *Silk Pavilion* in the final goal, I was interested in presenting the spatial perspective of the worm through the machine design, to try and probe into inner workings of the silkworm's worldview. This became the new design premise for *Machine II: Spatial Spinning*.

I started conducting my own spatial spinning experiments with silkworms, both looking at how the insects navigate through space individually and collectively. For the collective experiments, I cultivated silkworms that produced multi-colored silk using both the Singaporean method of feeding colored feed to the worms[6], and the Japanese approach of genetically engineered silkworms[7]. Through color tracking methods, I was able to observe the negotiations of two worms spinning in a common space, and how they built upon each other. It was surprising to find that there was very little mistake, back and forth or overlap in collaborative silk spinning, where the spatial territory of worms were clearly marked through the differentiation of silk color, as if it were following a predetermined blueprint.

Further research into areas such as sensory ecology and animal architecture provided a clearer explanation for what I was observing. In the case of insects that build, as the complexity level of their brain is limited, they instead utilize basic aspects of their body morphology, such as size, shape, and function, almost like a measuring stick to help predict and understand their surrounding. Over thousands of years of evolution, this relationship between and form and function is fine-tuned to such a degree, that the behavioral process that emerges can stand to be simple and mechanical, while ensuring complex, guaranteed results.

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[5] *Need to check and add paper citation here.*

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[7] *Need to check and add paper citation here.*

The goal I set for *Machine II* was to disrupt this equilibrium of insect perception, to introduce confusion, and to track that blindspot of the organisms through spun silk structures. The design of the vertical spinning mechanism starts from the basic form and size of the glass spinning chamber, each slightly beyond the reach of a fully developed healthy pupa. The curvature surface of the glass prevents the worm to identify corners and angles, which it utilizes to up a 3-dimensional framework for its silk construction. The vertical spinning motion of the chamber is based on the silkworm's sense of gravitational pull, where the slow spinning provides a constant change of gravitational direction, confusing the insect's spatial orientation.

Currently, I am in the process of developing the third and final installment of this series. *Machine III: Levitation* will begin to explore a merging of the artificial and organic systems in finding a middle ground that lends bias neither to one nor the other. My hope is to illustrate a possible bionic utopia that invites observers to challenge and rethink possible futures to our current cultural, natural and technological realities.