Behavioral sculpture

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Thesis Proposal for the Degree of Master of Science at the
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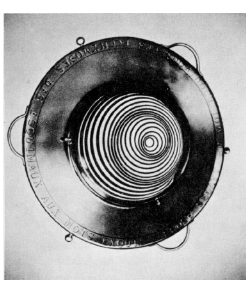
1. Abstract

Integrating information processing and networking technologies into kinetic sculpture creates new opportunities for exploring the aesthetics of movement and interaction. These technologies enable artists to create sculpture that can receive, store, modify, and transmit information and make possible a new type of work: computational abstractions of living biological systems. These abstractions can be imbued with reflex, affect, and the ability to communicate through combining electrical sensors, digital logic, and communications technology. By using a behavior-based software architecture to control a sculptures movement, complex series of coordinated motion can be performed in response to the sculptures environment and in relation to its internal state. Adding behavior to sculpture changes the interaction between people and the sculptural form. As people directly affect the movement of the sculpture the results of this interaction can be stored by the sculpture and used to modify the course of future interactions and behavior. This provides a foundation for a new dialog between the sculptor, the sculpture, and the audience.

2. Sketch for a behavioral sculpture

Existing within the context of kinetic sculpture, behavioral sculpture is an largely unexplored area of inquiry that has been made viable by advancements in microprocessor and sensor technology and the design of behavioral software architectures. By merging these technologies and ideas with kinetic sculpture, a new form of expression potentially opens up for the artist. It is my intention to show that this synthesis can lead to the creation of a new and viable art form that will revitalize kinetic sculpture. As proof of this concept I will create a sculpture which uses a behavior system to control the movement of its physical spatial form and as its method for interacting with people.

A behavioral sculpture is a sculpture that couples its perception and action by processing input through an action-selection system. Actions are chosen in relation to the current input and the internal state of the system. A behavioral sculpture has goals and works to achieve them by constantly monitoring its environment and changing its actions accordingly. A behavioral sculpture has a potentially different relation to its viewers than other forms of sculpture as the interaction between the sculpture and its environment (which may include people) determines the movement of the form.



1. Marcel Duchamp, *Rotary Demi-sphere*, 1925.

A systemic relationship between behavioral sculpture and other forms of art and sculpture is shown in Table 1. Based on this categorization, sculptures such as Alexander Calder's mobiles and Marcel Duchamp's *Rotary Demi-sphere* (FIG. 1) are not behavioral. Sculptures dynamically similar to Duchamps are considered to be absolute. Their input

Table 1. Categorization of systems

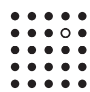
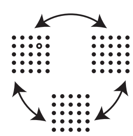
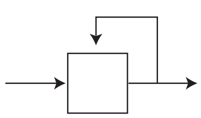
		REPRESENTATION	PROPERTIES	EXAMPLES: 2D Art	EXAMPLES: Sculpture	EXAMPLES: Other References
STATIC			*nouns, objects*	*Construction 99, El Lissitzki* *Flag, Jasper Johns*	*Bird in Space, Constantin Brancusi* *(name), Michael Grey*	
DYNAMIC	Absolute		*predetermined input creates predetermined output*	*Contempt, Jean Luc Goddard* *Pas de Deux, Norman McLaren*	*Loop, Len Lye* *Rotary Demi-sphere, Duchamp*	*Canard, de Vaucanson*
	Reactive		*variable input determines variable output* *n variables create an n dimensional system* *no concept of time or internal representation*	*Reactive Square, John Maeda*	*Mobile, Alexander Calder* *14 Balls, Pol Bury*	
	Active		*processes, stores information* *computational, internal representation* *autonomous, conditional, feedback* *varying scale from nearly reactive to highly symbolic*	*Programmable Ink, John Maeda*	*CYSP I, Nicolas Schoffer* *Telerobotic Garden, Ken Goldberg*	*Ghengis, Rodney Brooks* *Silas T. Dog, Bruce Blumberg*

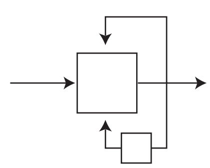
Table 2. Active Systems

simple representation → high level representation



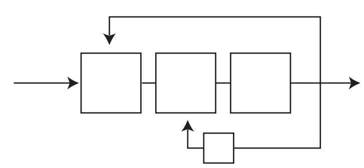
Behavioral

couples perception and action by processing input through an action-selection system. actions are chosen in relation to the current input and the internal state of the system. a behavioral system is goal oriented



Adaptive

system changes over time to enable it to perform more effectively within its environment



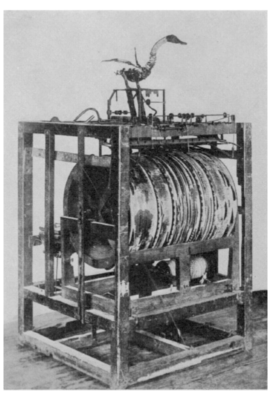
Deliberate

traditional artificial intelligence planning system. translating perception to action involves a linear process of sensing, modeling, planning, and then action.

is unwavering and predetermined with each output directly corresponding to a position in time and without regard to a changing environment. Mobiles and similar systems are classified as reactive. Their variable input determines a variable output, but there is no internal representation or concept of time. Table 2 defines different levels of complexity in active systems. In contrast to adaptive and deliberate systems, a behavioral system does not actively model its environment and is without the ability to modify its basic actions.

The behavioral sculpture I am proposing to build will have a concept of aesthetic equilibrium and its goal will be to maintain this balance. In order to do this the sculpture will have a representation of itself and be able to modify its position in regard to the discrepancy between its current state and a desired state. Therefore, as environmental stimuli affect its internal state, it will respond to maintain a favored state. This sculpture will have the potential to develop a deep interaction with the viewer as an aggregate of past interactions will define the quality of the present interaction. Over time, viewers will be able to learn how to stimulate the sculpture to gain a desired response.

From a more humanist viewpoint, the proposed sculpture will focus on physical forms in relation to the human body as well as the psychological connections created through dynamic interaction. The sculpture will not be one object, but multiple constructions creating different relations to the individual: inside, outside, above, below, near, far. Multiple people will be able to interact with the work at the same time, thus creating an environment for people to interact with each other either in response to the sculpture or to direct it. My principle goal is to create a profound intellectual and emotional experience unique to this new medium—a pioneering work of art.



2. Jacques de Vaucanson's *Canard*, 1738.

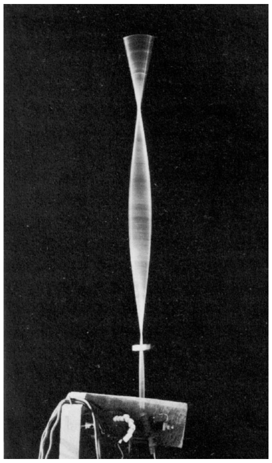
3. Context

Behavioral sculpture does not exist as a formal field of study or category of art. There are, however, related histories and contemporary practice which provides a dense background and context for the work proposed in this document.

3.1 Automata

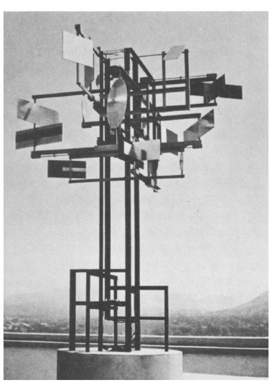
Automata are "seemingly self-propelled or self-animated images of men or animals" [Burnam 67] and have focused on the recreation of natural movement through complex deterministic mechanical systems. Articulated figures capable of pouring wine have been dated from third century B.C.E., but extremely realistic facsimiles of man and beast were not created until the Eighteenth Century. Jacques de Vaucansan's famous *Canard* (FIG. 2), exhibited in 1738 flexed its wings, ate grain, and executed a crude form of digestion. Its realism is said to surpass any machine made before it. Automata have always been technically advanced and has made use of the most sophisticated techniques and materi-

3. Henson's Creature Shop electromechanical pig and dog for movie *Babe*, 1996.



4. Naum Gabo, *Kinetic Construction*, 1920.

5. Pol Bury, *14 Balls each surmounted by a cube*, 1965



6. Nicholas Schoffer, *CYSP I*, 1956.

als available. The modern heir to mechanical automata is not contemporary kinetic sculpture, but the electromechanical animatronics systems used in Hollywood films (FIG. 3) and at rides in amusement parks and in current research dedicated to creating humanoid and animalian robots. Although automata appear to exhibit behavior, but their movement is predetermined and is therefore not behavioral.

3.2 Kinetic sculpture

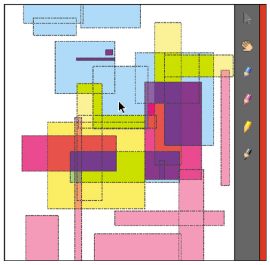
Unlike automata, the history of kinetic sculpture has focused on abstract and diverse concepts of motion and has traditionally been technically naive. As pioneered by Naum Gabo (FIG. 4) and Marcel Duchamp in 1920s and innovated by early pioneers such as Alexander Calder, Man Ray, and L. Moholy-Nagy, kinetic artists constructed grammars of moving form that have focused on both reactive and absolute systems (TABLE I). The work of Jean Tinguely combines both types of movement in his constructed self-powered machines that express mechanical disorder. In *Homage to New York*, Tinguely built a huge machine which moved from ordered movement to chaos as it slowly destroyed itself. In contrast to the overt movement of their predecessors, a second generation of kinetic sculptors explored barely perceptible motion. Pol Bury's geometric wood constructions slowly change as the linked elements grind against each other (FIG. 5). The contemporary sculptor Charles Ray has also explored subtlety of movement in his depiction of seemingly static objects such as his *Ink Line* which is a flowing line of ink from ceiling to floor that appears to be a black string. The work of these artists often utilize technology that is over one hundred or more years old. Their innovation is perceptual and cultural.

3.3 Computational kinetic sculpture

The history of computational kinetic sculpture is brief and a poorly documented story. Initially inspired by the writings of Norbert Wiener, sculptors such as Nicolas Schoffer created the first pieces of electronically responsive sculpture in the mid 1950s. In *CYSP I* (FIG. 6), Schoffer created one of the first pieces of sculpture that electrically responded to its environment. Moving in response to light and sound, CYSP I turns its blades in response to different colors and loud noise makes it still. The pioneering Cybernetic Serendipity show at the ICA in London was the first public introduction to this work, exhibiting computational sculptures from more than twenty artists. Although reactive, this work can not be considered behavioral because of its lack of representation and inability to adapt its actions to its environment. The recent work of Ken Goldberg has added a new dimension to the medium by pioneering teleoperated robotic sculptures (FIG. 7). Other notable contemporary practitioners include Alan Rath and Simon Penny.

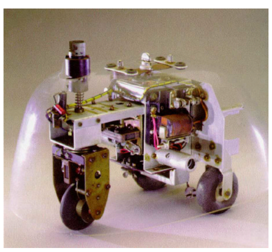
3.4 Behavior software

Many of the ideas discussed in this proposal are generated from the study of

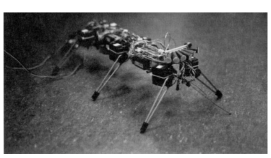


7. John Maeda, *Programmable Inks*

behavioral software. In the 1980s Rodney Brooks, Patty Maes, Marvin Minsky, and other researchers developed new ideas about behavioral artificial intelligence. These systems all shared the common theory that intelligence could emerge from the interactions of simple behaviors. An example is Brooks' parallel subsumption architecture, which managed to acheive goals without a central planner or controller. More complex and ethologically inspired models for behavior have been developed by Bruce Blumberg and Demetri Terzopoulos. Blumberg's *Silas T. Dog* character uses direct sensory input and a simulated vision system to navigate its envionment and interact with humans. Terzopoulos' physical simulations of fish execute high level activities such as feeding and mating through translating actions into control signals to their simulated muscles. A different kind of behavior system is the *Programmable Inks* (FIG. 7) system build by John Maeda. In this system, colored rectangles are programmed through a series of pull-down menus. When the blocks touch each other, they react according to their simple program, which results in complex behavioral movement on the screen.



8. Modern recreation of W. Gray Walter's Machina Speculatrix tortoises



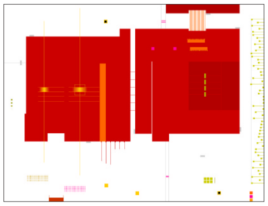
9. Rodney Brooks et. al., *Genghis*, 1989

3.5 Behavior-based robotics

In 1948, W. Grey Walter developed the mechanical tortoises, *Elmer* and *Elsie* (FIG. 8), the world's first autonomous robots. Each tortoise "was reduced to the equivalent of two nerve cells reacting to stimuli: two vacuum tubes, two relays, two condensers, and two electrical motors" [Burnam 67] were the main components augmented by a photoelectric cell which allowed it to navigate toward the light and gave it the appearance of being afraid of shadows. Unlike automata, Walter's creations were not a visual imitation of nature but a functional one. Since Walter's pioneering work, both the hardware and software for creating behavioral robots has steadily improved. In the 1980s, Rodney Brooks wrote a series of controversial essays describing an alternative approach to building artificial intelligence. Based on the software architecture introduced in section 3.4, these constructions simulate the actions of simple living organisms through the interrelations of different software agents. These ideas have been incorporated into recent research projects such as Brook's *Ghengis* (FIG. 9), Nasa's *Mars Sojourner*, and in emerging consumer products such as Sony's entertainment robot, *Aibo*.

4. Execution

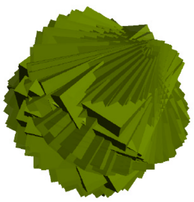
My proposed work in behavioral sculpture is a natural progression from the work I have been creating over the previous year. The study of behavioral sculpture builds on my research in dynamic interactive composition, time and motion studies, and adds the additional component of a behavioral software architecture.



10. *Egg Machine*, 2000

4.1 **Egg machine** Winter 2000

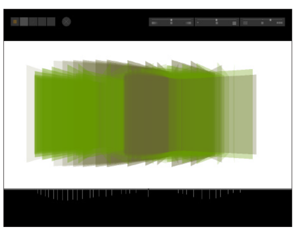
The *Egg Machine* project (FIG. 10) was the beginning of my pursuit to build behavioral systems. It explores the concept of visual ecology and focuses on interrelations between parts in a complex composition. As an overtly determinate system, its interaction is limited to parameterized constraints and the quality of interaction does not change. While working on this project, I began to learn about computational behavior systems and became interested in combining the ideas of adaption with my visual systems to create a less predictable, but logical system.



11. *Time-motion study*, 2000

4.2 **Time and motion studies** Winter 2000

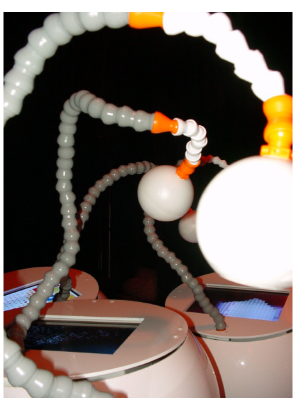
Interested in the property that virtual objects are unbound by conventional constraints of time and space, I created a series of animations (FIG. 11) where solid virtual moving objects occupy the same space as other objects, as well as exist in two places at the same time. The result of this work is a series of short animations exhibiting these concepts.



12. *Plane Modulator*, 2000

4.3 **Plane modulator** Spring 2000

The *Plane Modulator* (FIG. 12) system was created for analyzing and experiencing relationships between time, motion, and space. The user creates complex motion and volumetric forms by manipulating the time and spatial relations of periodically moving geometric primitives. Multiple frames in time are compressed into a single plane and translating the geometry about the horizontal and vertical axes expose the relative movement. At the end of this project I became interested in exploring these ideas with physical objects moving in real space.



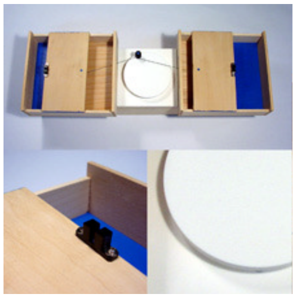
13. *Introspection Machine*, 2000

4.4 **Introspection machine** Summer 2000

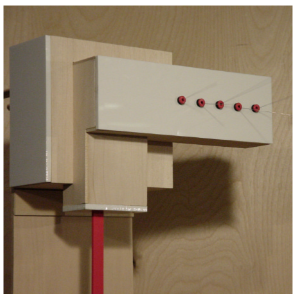
This visual feedback system integrates sculptural form, video input, and parameterized visual compositions (FIG. 13). Five modules, each with its own video input, processor, and monitor display separate images which are constantly reacting to the input from their camera. The software system I created for the *Introspection Machine* focuses on building dynamic form which reacts to changing environmental light. The video input is converted to numeric values representing light and dark pixels, and the screen graphics are treated as unique apertures, opening and closing in response to these values.

4.5 **Reactive boxes** Summer, Fall 2000

As a precursor to developing a large computational sculpture, I devised a series of three interaction studies to explore various ways of reacting to sculptural systems and to explore different types of transducers and actuators. The first study is physically reactive (FIG. 14) and its motion is triggered by touching one of two sensors mounted on the surface. Each sensor moves the sculpture in opposing directions and when both are



14. *Reactive Box 1*, 2000



15. *Reactive Box 2*, 2000

activated the motion is terminated. The second study has a remote interaction via the internet (FIG. 15). Sending a stimulus triggers a solenoid and the temporal difference between stimuli is calculated to modulate the speed of a DC motor which turns a series of wires. The third study has an ambient interaction and uses the sound and light levels in the room to generate motion.

4.6 Behavior software architecture Fall 2000

By January 2000 I will complete a generalized control system for behavioral sculpture. Its primary function will be to filter stimuli from the environment and use this information to select which action or set of actions the sculpture should execute.

4.7 Final plan Fall, Winter, Spring 2000–2001

The results of my research into kinetic form and interaction will be synthesized into a plan for an ambitious behavioral sculpture. The goals and constraints for this project are discussed in section 2 of this document. A detailed plan will be completed by January, and building will commence in February 2000 to be completed in early April.

5. Evaluation

The visual experiments leading up to this proposed thesis work have been evaluated in continual critiques by my peers in the Aesthetics and Computation Group, and my advisor, John Maeda. The evaluation for my proposed work will take place over the course of the Winter and the Spring through a series of critiques with my thesis advisor and my readers, who are experts in behavior systems, sculpture, human-computer interface design, and computer science. The sculpture will go through an iterative design process of planning, implementation, critique, and refinement. I will build a prototype of a sculpture, get feedback and comments, and then incorporate these ideas back into the work until there is agreement that the sculpture is complete. The proposed work is intended to be primarily evaluated as a work of art and is therefore to be judged based on its conceptual and aesthetic merit in reference to the history of art and its relevance to contemporary culture. After completion of the sculpture, a secondary evaluation will take place in the exterior artworld through submissions to international festivals and competitions such at Siggraph, Ars Electronica, and ISEA.

6. Thesis readers

John Maeda is Sony Career Development Professor of Media Arts and Sciences, Associate Professor of Design and Computation at the MIT Media Laboratory, and leader of the

Aesthetics and Computation Group.

Bruce Blumberg is an Assistant Professor at the MIT Media Laboratory where he directs the Synthetic Characters Group. His research focuses on the design of autonomous characters through integrating ideas from ethology, classical character animation, and artificial intelligence.

Michael Joaquin Grey completed a BS in genetics at the University of California Berkeley and received his MFA with a concentration in sculpture at Yale University in 1990. He has exhibited internationally, has been included in two Whitney Biennials, and won the Ars Electronica Golden NICA award in 1994 for *Jelly Life*. In the mid 1990s he founded Primordial, Inc. which produces *ZOOB*, a construction system using genetic models as plastic building blocks.

7. Resources

The proposed research in kinetic sculpture requires material resources including motors, energy sources, industrial materials, electrical components, and microcontrollers. In addition, it requires access to numerous machine tools for construction and computers for software development. The materials will be kept to a minimum through practicing a design principle of light construction, but about twenty small motors and as many microcontrollers will need to be obtained. All machine tools are accessible from the MIT Hobby Shop and all computers necessary for development are currently available at the Media Laboratory.

8. Timeline

12/00	Begin to write behavior software
01/01	First sculpture iteration and critique 05/01/01
02/01	Sculpture critique 16/02/01 and revision 23/02/01
	Write thesis background section
03/01	Sculpture revision 02/02/01 and 02/09/01
	Continue writing thesis document
	Complete final build of sculpture
04/01	Continue writing thesis document
05/01	Complete and deliver thesis

9. Deliverables

The primary deliverables will be an instance of behavioral sculpture, described in Section 2 of this document, and the thesis itself. The thesis document will contain a description of related work in both sculpture and robotics, a overview and analysis of my work leading up to this thesis work, a refined definition of behavioral kinetic sculpture, and documentation/analysis of my final thesis project. I will also complete an in-depth web and video documentation of the final sculpture.

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