Artiificial Life, Intelligence and Symbiosis

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Abstract

While biological systems have always served as worthy starting points from which to study, emulate and model artificial life, biological intelligences do not exist in individuals alone. There is an intrinsic structural coupling between all levels of living matter, which is emergent, with matter, energy and information at system levels above and below it. Consequently, approaches to machine intelligence and artificial life should also be expanded to incorporate and consider complex environmental and behavioral entities. Natural living systems are competitive, communicative and symbiotically intertwined and yet we have few examples of functioning machine installations, which are designed to exhibit bio mechanic symbiosis. Ken Rinaldo will look at his artworks and scientific investigations, which expand notions of artificial intelligence, biological art and artificial life, to exhibit levels of emergence. He proposes that an awareness of ecology and symbiosis in biological systems can point to software and hardware approaches, which look to the environment in which our intelligent machines may arise, emerge and intertwine.

Key words:
Media Art, biotechnology, artificial life.

VIDA, INTELIGENCIA Y SIMBIOSIS ARTIFICIALES

Resumen

Mientras que los sistemas biológicos siempre han servido como puntos de partida dignos desde los cuales estudiar, emular y modelar la vida artificial, las inteligencias biológicas no existen en individuos solamente. Hay un acoplamiento estructural intrínseco entre todos los niveles de la materia viva, el cual es emergente, con la materia, energía y la información en los niveles del sistema encima y debajo de él. Por lo tanto, los acercamientos a la inteligencia y vida artificial se deben también ampliar para incorporar y considerar entidades ambientales y del comportamiento complejas. Los sistemas vivos naturales son competitivos, comunicativos y simbióticamente entrelazados, y sin embargo se tienen pocos ejemplos de instalaciones de máquinas en funcionamiento, diseñadas para exhibir bio simbiosis mecánica. Ken Rinaldo mirará sus ilustraciones e investigaciones científicas, que amplían las nociones de inteligencia artificial, del arte biológico y de la vida artificial, para exhibir niveles de aparición. Él propone que un conocimiento de la ecología y de la simbiosis en sistemas biológicos puede señalar a acercamientos del software y hardware, que miran hacia el ambiente en el cual nuestras máquinas inteligentes pueden presentarse, emerger y entrelazarse.

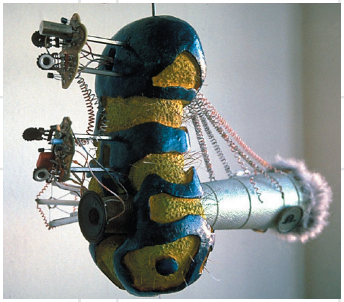
Palabras clave: Media Art, biotecnología, vida artificial.

> Humanity has just entered what is probably the greatest transformation it has ever know… something is happening in the structure of the human consciousness. It is another species of life that is just beginning.
>
> Pierre Teilhard de Chardin

My research into living systems, and the notion that playing with a pet or simple insect can be immensely satisfying, put me on a path 18 years ago to create sculptural objects and installations that appear to have life. Since we exist in physical space and do not question our state of "being alive", it seemed logical that, in order for the works to have the aura of "being alive", they needed to exist in physical space. This progression of my artwork involved the development of unique interfaces for humans and other species, as well as the development of approaches to artificial-life programming techniques. This research also confirmed for me, that corporeal and body oriented experiences, can offer fully engaging points of entry into software and hardware based interactive agents and spaces and can provide complex and friendly environments for living creatures.

In 1988 I began this work with reactive and auditorily complex sculptures called the Cybersqueeks (1988-92) which responded with cooing sounds and flashing fiber-optic lights when triggered by human touch. They function as simple rule driven cellular automatons in creation of collective chaotic behaviors. The sounds of one work triggered and modified the sounds of another Cybersqueeks, as the analog sound systems that triggered the works were also sensitive to light. When the Cybersqueek that was integrated with a fluorescent light was activated by the sound of any Cybersqueek it modified the light environment such that all the Cybersqueeks were then effected and their sound output was then changed.

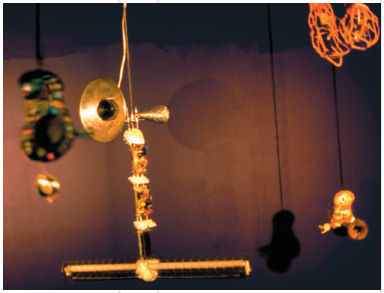
Cybersqueek with fiber optic hairs and light sensitive eyes which modulate the voice of the creatures.



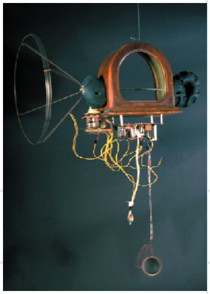
Cybersqueek with blue LED fiber optic hairs and fur to bring the hand of the viewer into the work.

The *Cybersqueeks* were helpful in allowing me to identify human "attributions of intelligence" as playing one key role in creating the impression of "being alive", which toys like Furby and AIBO have more recently been exploiting. These works allowed me to explore materiality and how our relation and associations to materials can function to draw the hands to touch, while creating mental associations, which may also transcend cultural learning. The use of fur, emphatic sound and scale were central in creating a desire to nurture these artificial creatures. I have wondered why most of these works sold to woman. Perhaps their scale (about the size of a fetus) their biomorphism and crying voices may have connected to unknown primordial urges.

My next work *Delicate Balance* (1989) explored the dissolution of natural environments and animal extinction. After researching fish sight and the ability that animals have to mentally map their environments I created a custom interface that allowed a Siamese fighting fish (*Betta splendons*) to move a glass fishbowl along a steel tight wire utilizing custom sensors. When the fish chooses to move it's fish bowl to one end of the wire it swims to one side of the bowl. When the fish arrived to one side of the tight wire under a tower constructed of



Cybersqueeks with sound activated fluorescent light. The sound of the other Cybersqueeks activated this light, which then changed the frequency of the other cybersqeeks to create a cacophonous soundscape.



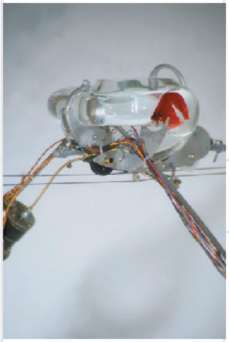
Cybersqueek with tube radio was part of soundscape created.

aluminum and branches, it found it's own image in a compact mirror, which was mounted, on a structure. Upon seeing its own image, and believing this was another opposing male it spurred the fish to build a larger bubble nest to attract prospective females to contribute their eggs to that nest as opposed to another.

The work was also designed to challenge and question issues surrounding our lack of respect and sensitivity to less powerful living creatures. Here the fish is empowered to move it's bowl, but the two directions that the fish are permitted to move the bowl is not much of a choice at all and underlines human hubris in thinking we can always manufacture and control natural environment through management and engineering.

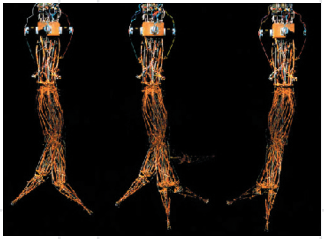
Delicate Balance further organized my thoughts about interface design. I was pleased that the Siamese fighting fish was able to use the interface, even though it clearly did not understand how the interface worked. Of course many humans also do not understand how automatic doors sense us, but we do know the door opens when we approach, to enter a building and through this association learning takes place. Delicate Balance led me to postulate that interfaces could be transparent, invisible or unseen by the user and simultaneously could be successful in allowing interaction and participant learning. For me, transparent interfaces are sensor-based feedback loops where an animal or human does not need to understand how

The *Delicate Balance* fish bowl moving towards the compact mirror.



Close-up of the red Siamese Fighting fish looking back at the viewer.

the system works, but nevertheless can begin to associate their behavior with the action or reaction of the art system. The ideal interface already knows about the user environment and should be able to anticipate and react appropriately given different situations. Another lesson learned in this piece was that natural materials can and do create visual complexities that are still difficult to create virtually.



This strobe shot captures the multiple positions of the three arms interacting. Audible telephone tones are their language, while they move toward human voice but away from human bodies. When one arm senses a person it sings that position to the other arms that respond by moving in that direction. Photo by Liz Zivic of San Francisco.

The Flock was my next experiment in creating a unique and corporeal experience for humans as well as robots. This artificial life work was made in collaboration with Mark Grossman (1993-4), and was a series of three robotic sculptures that communicated with both the viewer-participant and each other, showing complex behavioral manifestations based on this intercommunication.

Two interactants and one arm of The Flock. Here the arm approaches the interactants and sings their position to the other arms. Siggraph 1993.

Arms of the sculptural flock, were able to sense the viewer by triangulating sound from multiple microphones to localize the direction of the sound. When the sound was perceived by an arm it would communicate this back to the other members of the flock and they would indeed flock toward sound. Custom infrared sensors were developed and allowed the sculptural arms to avoid bumping into the participants. A distributed network between the three robotic arms allowed two of the arms to accommodate and follow the first arm's movement manifested an inorganic flocking behavior. This was an early example of utilizing behavior-based artificial intelligence programming techniques to structure group robotic sculpture behaviors.

Another work entitled *Technology Recapitulates Phylogeny* biologically based artwork is both an observation I've made and a play on Ernst Haeckel's notion that "ontogeny recapitulates phylogeny", in which the ontogeny, or growth of the fetus in the womb recaps certain phylogenetic stages through which life has evolved. During gestation, humans progress from a single cell to a time when the fetus has rudiments of gills and a tail.

As you approach this piece an infrared sensor turns a light on which projects the worms and tree forms onto the walls and ceiling. The tubefex worms, which are the stars of this piece, demonstrate a form of supra organization in which these single tubefex worms act together to form a group consciousness of thousands of worms. The gaggle sends out exploratory tentacles projecting from the edge of undulating masses, which resemble magnified striated muscle cells. These collective fingers project over the edge of the plate and back into other writhing masses. If you touch one worm in a bunch the whole mass contracts like a flinching muscle

The roots, worms, and circuit boards in this work point to the all-pervasive tree structure as a most efficient matter, energy and information distribution network. Tree

Above the left frame holds an image of a circuit board on acetate. The two middle images hold human brain cells on acetate. The right form is an aluminum basket with a plate of live tubefex worms and a Hollyhock root underneath comparing various tree structures.

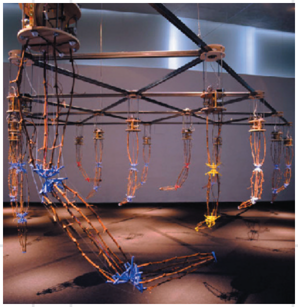
structures are forms that recur consistently in organic and inorganic systems alike. They may appear as fingers of rivers, cracks in rocks, branches of roots, snowflakes, cytoskeletons, brain cells, clumps of worms, circuit boards, and very large scale integrated circuits (VLSI), and internet connection networks.

Another biologically based work, titled *Mediated Encounters* (1996) permitted two Siamese fighting fish to utilize custom interfaces to move two, robotic-truss sculptures around and see each other across the gap of the glass. While they were permitted to meet each other, they were not able to fight in spite of having been bred to fight to the death.

This work created a feedback loop, which allowed real interaction between the two fish and the cybernetic structure. Females in two other glass bowls on the other ends of the grapevine-trusses served to tease and spur the males into competition. It is important to note that Siamese fighting fish have been bred to fight to the death and this has been exploited for years by fish-fight organizers in Thailand. Here the robotic structure became a kind of mediation of the fishes' human-manipulated genes, which genetically enhanced the fishes' desire to fight.

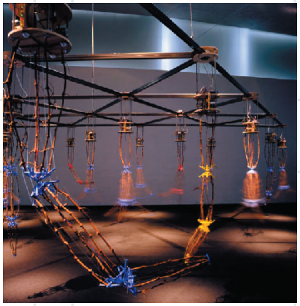
Autopoiesis (2000) is an artificial-life robotic series. *Autopoiesis* consists of 15 musical and robotic sculptures that interact with the public and modify their behaviors based on the presence of the participants in the exhibition and the communication between the separate sculptures.

Autopoiesis breaks out of standard interfaces and presents an interactive environment that is immersive, detailed and able to evolve in real time and space by utilizing feedback and interaction from audience member-participants. This physical interaction engages the viewer-participant, who, in turn, affects the overall group evolution and emergence as individual sculptures feedback to a central controller, which affects the system's evolution as well as an overall group sculptural aesthetic.



This is an overall photo of all fifteen arms of the Autopoiesis installation.

The phenomenon of Autopoiesis is a characteristic of all living systems, which are "self-making". This characteristic was defined and refined by Chilean biologists Francisco Varela and Humberto Maturana "Autopoiesis" translates as "auto production" from the Greek word *poiesis,* which means "production" or "creation". The theory focuses on autonomous systems as they are determined by their structure. For Maturana, autopoietic theory gets at the heart of the "constitutive dynamics of living systems" a dynamic involving living systems and their ability to structurally couple with their environments while maintaining self-referential structure. In *Autopoiesis*, the human environment affects the behavior of the robotic artworks, which in turn effects the behavior of the viewer. This allows a conversation of one reacting to, responding to and influencing the other in the creation of a unique robot-human evolution.



One of the blue arms of Autopoiesis is swinging to the right toward the photographer while the other arms dance in the background. Photo Yehia Eweis.

The robotic sculptures talk with each other through a serial network that interconnects all of the robots. They interact with the viewer-participant through a positional language and speak to the viewer-participant through audible telephone tones. Each sculpture also has two types of light-emitting diodes, which flash according to what the sculptures "see" in their environment, what data the individual sculptures receive from their neighbors and what the competing network behaviors are telling the individual sculptures to do. Each robotic sculpture also generates bit strings of information based on its interaction with the viewer-participant; the bit strings are fed back to a global controller and used as an internal numerical randomizer.

This shot shows two red arms of Autopoiesis each of which has a lipstick camera at the tip. What they see is projected back to the wall of the installation. Photo Yehia Ewies.

The randomizers affect overall sculptural form and the evolution of the sound environment as well as how vigorously the group moves and what behaviors are manifested. For example, when many people are present, the number of sensor activations tells the global microcontroller to choose from a vast series of behaviors that are less vigorous. When few people are in the room the sculptures respond by displaying a series of more vigorous group behaviors; it is now safe for them to move freely. If the network controller does not detect many sensor activations for long periods of time it induces the arms to go into a sleep mode, in

A close up of Ken Rinaldo in the studio producing the work. The super bright light emitting diodes were strong enough to cast blue light onto the walls.
Photo Amy Youngs.

which they will rest until one of the sculptures senses the presence of a nearby human and reawakens the group.

The telephone tones also serve as a kind of musical language that allows the individual robotic sculptures to give the participant a sense of the sculptures' emotional state within this interaction. Higher and more rapid tonal sequences are associated with fear; the lower, more deliberate tonal sequences are associated with relaxation and play, as is the case with actual animals. Other tones give the impression of the sculptures whistling both to themselves and to each other. The telephone tones are a consistent language of robot intercommunication and manifest a sense of overall robotic group consciousness, where what is said by one sculpture effects what is said by others. The telephone tones also invite attributions of intelligence as they give feedback to the human participants.

Autopoiesis utilizes a number of unique approaches to create this complex and evolving environment. It uses smart-sensor organization that senses the presence of the viewer-participant and allows the robotic sculpture to respond intelligently. I have used the term "smart-sensor organization" in past papers to describe the process of organizing the sensors in such a way that they can be minimized in number while maximizing the abilities of the software to cope with this data.

If properly organized, just a few sensors can be used to create complex interaction. For example, at the top of each sculptural element of *Autopoiesis* are four passive infrared sensors, facing north, south, east and west. When two sensors are triggered, the program knows that someone is located in, for instance, the southeast corner, and this is the direction toward which the sculpture moves. Four sensors allow eight quadrants of sensing. These passive infrared sensors tell each arm to move in the direction of the viewer, while an active infrared sensor located at the tip of each sculpture stops the arm as it arrives within inches of the viewer. This allows the sculpture to display both attraction and repulsion behaviors and lets the arms respond intelligently to an infinite number of situations involving one individual among a group of participants.

Furthermore, with *Autopoiesis*, the robotic sensors compare their sensor data through a central-state controller, so the viewer is able to walk through the sculptural installation and have the robotic arms interact simultaneously as a group as well as individually. Because each arm has its own on-board computer control, the overall speed of reaction is rapid and therefore lifelike. The software is organized to allow local interaction always to supersede group control when a local sensor is aware of a nearby human. This allows individual arms to show accuracy and delicacy of approach and avoidance when encountering the viewer-participant.

At the tip of two of the arms, lipstick cameras project what they see onto the walls of the space. This gives the viewer-participant a sense of being observed by this artificial-life robotic sculpture.

That *Autopoiesis* is constructed of dried grapevines is significant, as robots are generally constructed of steel and other more machine-friendly materials. The grapevines soften the works, make them more approachable and place them within the realm of the biological. The grapevines also demonstrate a kind of frozen cellular consciousness, which is fixed in time and evident in their dried form. Natural grapevine behaviors can be revealed with stop-action photography, to demonstrate vine tropism toward light, where vines are seen to wrap around other branches to climb toward the sun. Likewise in *Autopoiesis*, each sculpture moves toward the infrared heat of the human participants and mimics on a macro scale the behavior of the material from which the arms are constructed.

Autopoiesis continually evolves its own behaviors in response to the unique environment and viewer-participant inputs. This artificial life, group consciousness of sculptural robots manifests itself as a cybernetic ballet of experience with the computer-machine and viewer-participant involved in a grand dance of one's sensing, responding to and evolving with the other.

Spider Haus is a transpecies communication artwork constructed of stereo lithography plastic and a common house spider (Theridiidae). It is designed to amplify and connect the viewer with the delicate beauty of arachnids and point to the fact that the common house spider is a real urban spider, with few living outside of human habitation. Since the beginning of history, spiders have been viewed as threatening creatures and enemies of humans. Arachnophobia is a rampant deep primeval repulsion of spiders though spiders offer tremendous benefits to humans such as eliminating harmful insects from our environment.

This work is designed as comfortable home for spiders with a hybrid rapid prototyped plant, which has spikes for easy Web attachment. Bright blue LED's sit inside each flower and attract insects into the flower area and be ensnared in the spider's Web. A small video camera is mounted on the interior of the plant-like forms and focuses up at the Web-amplifying the spider environment to allow humans to observe and commune with them while mixing both humans and spider in this eco-techno-Web.

Many spiders have eight eyes though some have just six, and all have jaw structures called (chelicerae) which are claw-like fangs through which they can inject venom. Spiders produce venom that is poisonous to their common prey of insects. The venom is injected to immobilize and kill their prey. Digestive fluids are injected into the prey since spiders can only ingest liquids. Silk spinning glands are located at the tip of the abdomen. Spider silk is secreted through the spinnerets as liquid but hardens on air contact. A variety of silk created is to construct egg sacs, snares or Webs, draglines and ballooning threads. Common house spiders lay their eggs in ball-shaped silken sacs that are often carried by the female or hidden in the Web. A female can produce 3,000 eggs in several sacs over time. Eggs often hatch weeks later and can reach adult size in about one year. Spiders must shed their skin (molt) in order to grow and will do so up to twelve times before reaching full size.

Female house spiders are larger than males, about 1/3 inch long. In most spiders the females are usually larger than males. They commonly hang in the center of an irregular cobWeb upside down. The sticky threads entangle insects, which are the bitten and sucked dry.

The final work which I will discuss is Augmented Fish Reality (2004) which could best be termed as "biocybernetic" sculptures.

Augmented Fish Reality is an installation of rolling robotic fish-bowl sculptures designed to explore interspecies and transpecies communication. These robotic sculptures allow Siamese Fighting fish to use intelligent hardware and software to move their robotic fish bowls anywhere in the room.

As with many fish, Siamese fighting fish have eyes, which allow them to see for great distances outside the water. They can see color and seem to like the color yellow. They have the ability to mentally map their environments in finding food and avoiding predators. With the system design built the Siamese fighting fish have discovered the interface and choose to use it to move the bowls around while interacting with their environment. From the most recent research into fish intelligence in Fish and Fisheries, 2003 edited by Keven N Laland, Culum Brown & Jens Krause the articles discuss revisions about fish intelligence, which is much greater than formerly thought. Fish are now regarded as "steeped in social intelligence" and the report says "pursuing Machiavellian strategies of "manipulation, punishment and reconciliation" while also displaying 'cultural' traditions; and co-operating to view predators and obtain food. It is said that fish monitor the social prestige of other fish and track the relationships of other fish in their environment. It is now widely supported that fish use tools and build nests (bubble nests) as well as exhibit "impressive long-term memories". Fish have the ability to map their environments in finding food, creating relationships with each other and avoiding predators.

This design uses accurate infrared sensors around each bowl. By swimming to the edge of the bowl the fish activates motorized wheels that move the robots forward and back and allow the fish to turn the robots to switch directions.

Humans interact with the work simply by entering the environment. Still, these are robots under fish control and the fish may choose to approach and/or move away from the human participants and each other when they choose.

Close up for of Augmented Reality tank showing.

These bowls are large for Siamese fighting fish and consist of a living environment that includes peace lily plants that absorb and prosper from the fish waste and provide oxygen to the fish. Stones in each tank make their world friendly and more complex. The bowls and robots are designed to allow the fish to get to within 1/4 inch of each other for visual communication between the fish, both male and female.

In Thailand, Siamese fighting fish have been bred to be more aggressive and this give the fish extra motivations to utilize the interface.

Installation shot in Lille 2004.

An additional element is small lipstick video cameras mounted on forty-five degree angles under two of the bowls. These cameras image the interior of the fish bowls as well as humans in this environment. These video images are intercepted with transceivers and video projected back to the walls of the installation giving a humans a sense of both looking into the tank but also being in the tank. It puts the fish scale on par with human scale and gives the humans a view of what the fish are seeing.

In conclusion, in each of the interactive artificial life artworks and symbio-technoetic biologically based works described above, an awareness of ecology and symbiosis is asserted through amplification of action and experience for both the viewer and creatures being engaged. The natural environment has served as inspiration and model for my research into the creation of new interfaces, software and hardware approaches and my hope is for a continued increase in advances in artificial life/intelligence machines and biologically based works that find existence as physically manifested works.