Aesthetics of Biocybernetic Designs: A Systems Approach to Biorobots and Its Implications for the Environment

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ABSTRACT

The authors identify some of the theoretical premises of biocybernetic art objects, with reference to the works of Nam June Paik, Edward Ihnawitz, Ulrike Gabriel, and most notably, Gilberto Esparza, the Mexican biocybernetic artist. Systems theory anticipates stochastic convergences in nature, defying the classic certitude of the teleological notion of form. Evidence for this paradigmatic shift is found in the biocybernetic creatures conceived by these roboticists. In much biocybernetic art, beauty emerges in the form of adaptive mechanisms, such as in robotic tetrapods or self-organizing artificial plants. Such structures provide a template for survival mechanisms in an increasingly entropic environment.

Introduction

In this article we consider theory as an avenue for understanding the emergence of digitally controlled architectures, with specific emphasis on designs that have an aesthetic function within the scheme of natural human and non-human relations. The generic classification of art-objects is based on classical categories of mimetic production; but digital architectures stand in need of a new taxonomy in accordance with their emergence as ecopoietic precepts [1]—i.e. as technologies that emerge in nature, incorporating behavioral and simulative (mimetic) agency as their inseparable aspects. Proposed nomenclatures of arts produced by digitally mediated technologies are “artificial reality” [2], “systems aesthetics” [3], “cybernetic art” [4], “digital art” [5], and “biomimetics” [6]; but in our opinion the theoretical predictions of evolutionary adaptation (or exaptation) [7] and dispersal of such high-tech genres are yet to be correlated to the self-organizing entropy of such digitally autonomous artworks as the *Robot K-456* designed by Nam June Paik—the first, most successful and intellectually enduring piece of cybernetic art. Such classic works as Paik’s *Robot K-456* (1964), Edward Ihnawitz’s *The Senster* (1970), Ulrike Gabriel’s *Ars Electronica* (1993), Gilberto Esparza’s *Inorganic Autotophs* (2009), *Perejil buscando al sol* (2010) and *bioSonor ICN* (2012), and commercial offshoots like the humanoid NAO robot developed by Aldebaran Robotics in France, or the robo-artefacts of Hiroshi Ishiguro in Japan—all invite us to consider how cybernetic art has evolved. Digital applications in aesthetic realms can no longer be tied to classical metaphysics and notions of “form” or “essence.” We would like to argue that the quiet yet alarming revolution brought about by non-linear systems in nature [8] is beginning to open our eyes to a different kind of unpredictable principle in the universe and an emerging environment of stochastic realities and functional value-systems. Perhaps it is best manifested in early cybernetics and robotics. Evolution of a science of aesthetic conditions can only be appreciated if the uncertain graph of its future is taken into account, as well as the kind of mathematics that factors into it.

The emergence of systems-based sequences anticipates cybernetic designs for self-organizing, intelligent machines. Self-organizing systems have been studied following naturalist [9], physical [10], and ecopragmatist [11] terms, but such theory may have a specific correlation to the

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emergence of aesthetic processes. The *raison d'être* of self-organization derives primarily from a new philosophical suggestion that breaks down the propositions of classical aesthetics. Art is driven not by the aim of having to transcend nature (which is proverbially imperfect or sub-human), but of being in sync with the uncertainty principle of natural formations. The Greek and Eurocentric model—espoused by art critics such as Gombrich [12]—draws attention to the hidden notion of a perfect form that the artwork achieves. Systems theory recognizes the non-teleological character of formations—an idea that may not be grasped given the limited range of human vision. The artwork may be mathematically anticipated rather than concretely envisioned—the art of "artificial life," robotic functions, and simulations may emerge as discrete embodiments not to be known or to be identifiable in humanist terms. The biological organism appears to be a stable and recognizable structure with a set of defined behavioral tendencies. The intelligence of such organisms is modelled in accordance with behavioral modes and reflexes displayed towards the environment by such animals as the *robolobster* [13]—but it was perhaps with reference to the neo-Darwinian thesis of replicative evolution [14] that the stable ideas associated with any living, evolving organism, and a proto-Aristotelian metaphysics, came to be discounted. In modern theory, cybernetics posits an algorithm of evolutionary intelligence that can lead to completely unpredictable modifications in nature—such as self-replicating biomachines, creating a completely "artificial" reality [15].

Figure 1. ***Perejil buscando al sol*** **(*****Parsley Seeking Sunlight*****) by Gilberto Esparza. Feedback biorobot. Height 16 inches. © 2013 Gilberto Esparza.**

Algorithm

The mathematics for cybernetic art has to be understood in terms of a feedback loop—as a system of sensors, in which digital computation calibrates and simulates equilibrated responses. The mathematical algorithm on which feedback loops operate describes the conditions in which humanoid robots work. How does this system work? The data from sensors create an electronic pattern that channels back through a flow chart in order to generate another reflex in the robot's arms or limbs by means of actuators. Thus, as in air-conditioners that control the temperature of a room by feeding in sensory data of the room temperature at a given time, the adjustments for temperature-control are made only on the basis of feedback (an essentially closed feedback loop). The air-conditioner adjusts its thermostatic settings to acquire a target temperature. This is reminiscent of Fritjof Capra's example of a boat sailing towards a destination but getting deflected in its course all along the way by strong winds blowing against it, necessitating frequent adjustments to the course [16]. Such feedback loops may be used to trace how life forms are emerging—but also, more practicably perhaps, to understand how intelligent, i.e. responsive, systems are naturally adapting themselves to their environment. The main implication in terms of our perception of natural occurrences is to recognize the great mass of uncertain patterns—the entropic or chaos of probabilities and the notion of convergences. At the same time, engineers have been working towards approximating practical solutions. Let us take an example. The following chart demonstrates how a closed feedback loop is functional for the robotic installation *Perejil buscando al sol* or *Parsley Seeking Sunlight* (Figure 1). What we notice in such cyberaesthetic installations is the amount of adaptivity left out for the *perejil* or parsley plant: it continuously tries to receive sunlight (like a negative loop variable) by moving towards it with the help of wheels, in an environment of light and shade.

The data-analytical adjustments take place as sunlight impacts the sensors of the robotic plant and enables it to move from shade towards the light of the sun. The mathematical flow chart of the process might look like Figure 2, in which the numerical reading of the intensity of sunlight is denoted by S(*tn*). This reading, acquired from the photoreceptor for any moment (*tn*), is calculated against the numerical reading in the prior moment or point of time (*tn-1*). The difference or change in the value of the intensity of light is fed back into a controller, which propels the wheels toward the area in which the difference in the intensities of light, for two distinct moments, is eliminated. In this way the parsley plant is always oriented towards a space of maximum intensity of light. This is also precisely how the plant system acquires higher entropy for itself.

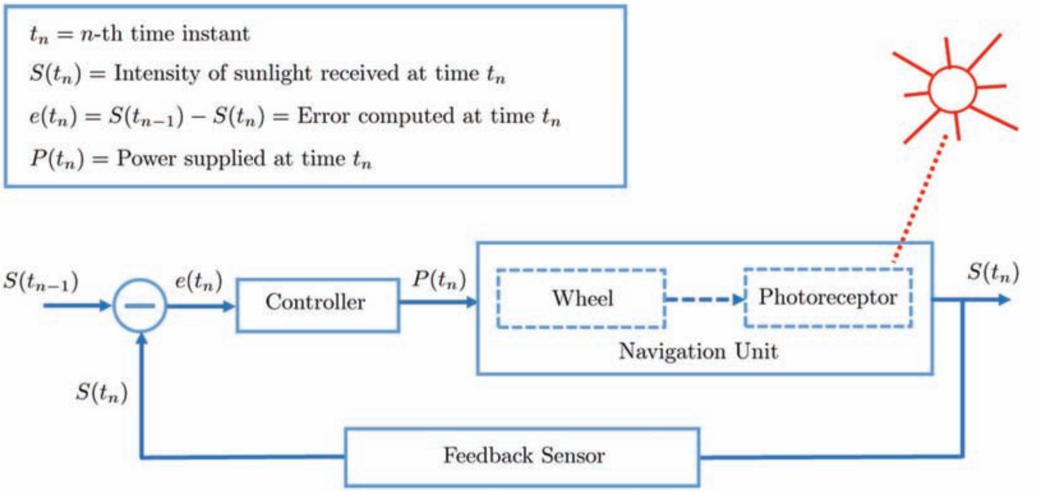

Figure 2. Closed loop control for *Parsley Seeking Sunlight*. Photoreceptors receiving sunlight help the conversion of data to digital information, which back-calculates error and activates a motor in order to move the plant towards a source of light. © 2014 Sujoy Biswas, University of California, Santa Cruz.

This installation therefore achieves its target by recuperating in sunlight, which it seeks out for itself. This kind of biomimicry creates a spectacular effect on the human observer, who gradually becomes conscious of a strategy for survival. It is the adaptive self-engineering of the plant that makes it a unique cyberaesthetic symbol of emergence in the natural world, revealing for the first time how the plant survives by computing against the possibility of its own desiccation across a space of uncertain illumination. The plant may not know exactly how to fixate itself in a world of unchanging luminosity, but only how to cope with its inevitable transitions in a changing, unknown, and uncertain context in relation to its future. Unlike the infallible garden of the classical imagination, the parsley inhabits a garden of uncertain illumination by adapting and surviving and adapting again and yet again in a continual manner.

Systems Ecopoiesis

Cybernetic art may therefore be studied in terms of a functionalist hypothesis: robotic agency can alter productivity and human relationships [17] by manipulating behavioral databases of social networks [18]. Entropic recycling leads to the emergence of a self-renewing environment and a holistic ecopoiesis. Cybernetics initializes ecopoiesis by creating a platform of machines [19]. In such a context the question of policy is rendered irrelevant. As robots begin to participate in the environment of the future, the quest for ethical or eugenic machines would have already been compromised by the pre-existence of human psychological categories and databases. Yet robots shall operate with behavioral inputs from nature in a way that may still benefit and enhance survival and the sense of aesthetic participation. The education sector may also be a sort of environmental beneficiary of digital improvisation and representations [20], more so in matters of assistance to learning and computation. Having acknowledged that robotics may provide an instrumental basis for future economics—the obvious choice for engagingly comedic art shall be one generated by cybernetically engineered mimicries of virtual situations. But such an axiomatic social order in which ecopoietically deviced robots will have a positive role to play shall have to take the domain of application into account [21]. Perhaps there should be a direct relationship between the domain > application integration for robotics; perhaps this way damage to the environment would be minimized, given what we know of the entropic functions of the universe. The manner in which robots shall modify human society will have to depend on consideration of databases like those relevant to a study of global warming and conservation of energy. Such patterns may be temporal models extrapolated from the larger entropic formation of natural systems. Robots such as found in Gilberto Esparza's *Nomadic Plants* (2010) or *Urban Parasites* (2010) or Nina Tommasi's *Biological Instrumentations* (2009) definitely aim to eliminate or reduce carbon emissions and help automatons create stable ecosystems. Though not yet achieved on a large scale, robotics can begin to operationalize environment-friendly systems.

A history of biocybernetic art would include such works as Paik's classic *Robot K-456,* Ihnawitz's *The Senster*, Ken Goldberg's *Telegarden* (1995), and Gilberto Esparza's *Nomadic Plants* (2010). All of these works directly implicate the question of environment; they carry the proposition: biocybernetics discards an obsession with the humanoid shape and begins to resemble a sort of feedback organism [22]. Esparza's robotics thus differs conceptually from such models as the *Telegarden*. Esparza's feedback systems are realized in terms of an entirely different and corporeally invisible focus in which the biosphere is affected and begins to change because of a certain kind of dynamic intervention. Norman White, an earlier developer of biocybernetic devices, had already identified this process as one deserving close attention. This development from merely interactive "telegardening" towards more complex algorithms is visible in bio-inspired works such as *ALife* [23] and sensitive systems such as Ulrike Gabriel's *Terrain-01* (1993) [24], in which robots act in sync with neural discharges to create an interplay of objects in a circular arena. Biofeedback loops are similarly used to build interactive systems, such as Tommasi's *Biological Instrumentations* on the one hand and Esparza's *Nomadic Plants* on the other—both of which employ sensors to translate the information into robotic movements, but in different directions. Tommasi's work saves a plant from self-destruction; Esparza's model devours waste products to give birth to and to sustain oxygen-producing plants. Thus the machine and the environment, albeit in a biologically connected manner, are engaged in a constant exchange with each other, giving rise to positive life-sustaining components in the eco-system.

Figure 3. *Plantas Nómadas* (*Nomadic Plants*). Feedback biorobot and geobacteria from waste and recycling for plants placed along a platform on wheels. 10 inches in height and 12 inches in width. © 2011 Gilberto Esparza.

Indeed, Esparza's *Plantas Nómadas* (*Nomadic Plants*) (Figure 3) is quite different from any other biocybernetic artwork heretofore conceived by roboticists. It consists of a biocybernetic mechanism that survives on solar energy, micro-biotic combustion cells, hydro-waste and natural plants. The complex system obtains nutrients from the polluted waters in rivers and derives energy from the remains of organic waste, as well as from solar energy through the use of two flexible solar cells installed on the mechanism. This bio-energy is stored in lithium batteries in order to keep the machine functioning. The hybrid machine-nature ecosystem tries to adapt itself to a negatively altered environment (in this case, the sewage waste on which the creaturely robotic plant lives). The adapted microprocessor, ultrasound and compass sensor, and bio-digester are all lodged in a skeleton based on a Voronoi diagram. Esparza's robotic machine purports to heal the wounds inflicted by the uncontrolled consumption and growth of an industrial society. While analyzing Esparza's device, we realize that it is a strange system of nature and machine living together, making a proposal for a new symbiosis of opposites: machine and nature, art and science, stillness and motion, creation and destruction, in an image of ecopoietic sustainability.

The most significant tendency visible in this context is that of the increasing ability given to the robot by the array of multiple sensors, which builds on an algorithm of signals to generate control over the ecosystem. Interchange of information collected by a system of bio-chemical sensors makes the robot highly efficient and even capable of making decisions. Increasing complexity achieves maximum entropy. This explains the widening horizons of efficient robots that have discarded humanoid modules for the complex virtues of biological ecosystems. Robots shall no longer look like men or women, but rather like combined biomorphs whose functional efficacy within selective environments enables them to adapt, move, and perform specific functions with greater skill. Thus tetrapod appendages are recognizably better instruments of locomotion on three-dimensional surfaces—rather than wheels or bipedal locomotors [25]. There has been a definitive shift from human-centered robotics towards the development of amphibious, arboreal, or drone mobility and orientations that are more efficient for transportation and labor-intensive tasks in a human environment. Current research on cybernetic modeling aims to simulate movements of quadrupeds or other entomological organisms that can move through various levels and densities of physical media [26]. Frank Grasso has already applied the term *biomimetic*, in the US Navy–funded project *Robolobsters* [27], to design environmentally decisive robots that can defuse a bomb, serve functions of physical defense, or even perform lower-level functions such as cleaning polluted sub-marine locations. In every case, cybernetic architectures exploit optimal zoomorphic feedback for controlling locomotor actions.

Conclusions

It has been suggested that negative loop systems, like a missile cruising towards a moving target, continuously deviate from a physically located target—hence the need for continually updated, sensor-driven information so that a system can reduce error and function on the basis of approximation. Nevertheless there still seems to be a space of maximization for agents within the spectrum of natural experiences. Machines may also adapt to changing environments, if the algorithm can be made to accommodate such shifts. Survival of systems, like Esparza's robots and those of some of his predecessors, begs the question of self-replicating robots [28]. Adjustments would be effected by neurotrophic interactions of the sensors on such robots as in *Nomadic Plants*, because it is a eugenic robot designed to stabilize the environment and make it more hospitable for its human agents [29]. George Chirikjian refers to a specific path for replication. Could a robot, like Esparza's nomadic plant, self-replicate like a reproductive entity? Could it spread across the domain, producing noble gases and creating more vegetation? The question, like that of science fiction cyborgs, might appear to be in the distant future; however, its practicable dynamics have already been captured in discreet models in which robots placed in specific domains will construct another robot from material available in the environment. In the final analysis, cybernetic art suggests the birth of a new kind of companionship between organic and electronic components. This is unlike the "do-it-together" model, or "perform-together" art in which a subject with conscious intentionality synchronizes with a machine, just as happens during a performance recital. In its place we become witnesses to the birth of a new species. Biorobots will be electronic creatures embodying self-replicating biocybernetic systems. This art cannot have a particular form, and its discussion under the heading of a specific artist is likely to fossilize art history in the manner of Gombrich's classical worldview. The biocybernetic form is a mathematical possibility. If it is accidentally born out of a negative loop it may well be invisible or exist incorporeally like a discrete architecture or matrix embedded through real and virtual frames of simulation [30]. It may not resemble any known intelligent species [31]. None of the classical certainties of aesthetic objects will have survived in the new environment. Art will emerge as a feedback mechanism only in order to survive in real time. Thus, there shall be two modalities for this kind of artificial life: (a) biorobotic simulations and (b) self-replication. Both models have succeeded in arising independently, but they may also combine to form new systems and (non)-entities.

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