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Artificial Ecologies

Artificial Ecologies: Second Nature Emergent Phenomena in Constructed Digital – Natural Assemblages

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Abstract
The paper presents work conducted at the Architecture and Urban Research Laboratory (A+URL). A+URL conducted investigations into artificial ecologies and metabolic systems and asked participants to develop projects that learnt, borrowed, or stole from natural systems. In essence, constructing part natural/part artificial assemblages functioning as small-scale quasi-ecosystems. Microprocessors, sensors, human inputs and feedback systems, dead washing machines, plotters and fruit were employed to construct these. The outcome(s) of the work was a garden of strange delights. And as in any garden where things can grow wild, a level of unpredictability of outcome arose, freed from constraints of orthodoxy.

Introduction

Changes wrought in the natural world at large are resulting in an environment that has been altered to the point that the natural biotope no longer exists as a normative condition. At the same time, the ubiquity of the digital realm has altered our relationship with the natural world in profound ways, becoming our prosthetic extension to the world. As these two trajectories — one natural, one digital — develop, new possibilities open up for situating a condition both natural and digital at the same time: a hybrid condition full of entities that belong not to one single environment but able to exist in either — in other words, a second nature. This paper postulates one possible version of second nature, termed here, Artificial Ecologies, an exploration into constructed synthetic environments developed, manufactured, and tested through post-graduate design studio work and research projects conducted at A+URL. This work is aimed at generating dialogues and crossovers between natural systems and cultural or synthetic systems, through making and testing electro-mechanical systems whose behaviors and interfaces reflect a studied natural system.

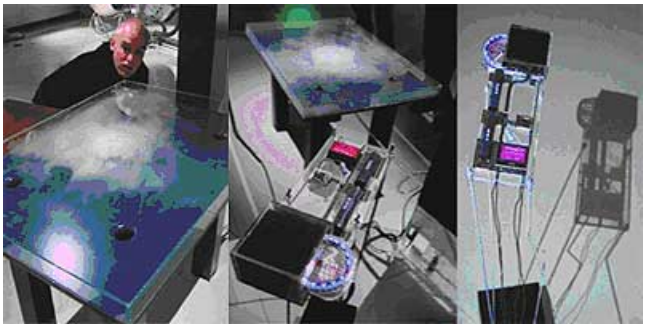

Figure 1: The Fog Table: Magnetic field sensitive fog cloud table

A 'second nature', as a hybrid digital-bio-tope fusing both nature and artifice, is an environment in which some aspects of the digital wild may dwell. Natural and artificial, physical and digital simultaneously, this environment is a liminal condition [1] allowing for diverse kinds of hybrid cybernetic species to develop. Within, we might find the wild or the unexpected, part beast and part machine, each the union of different species, phyla and lineages, a population informed by mimesis from nature yet suffused with the soul of bits. Digital entities not able to be placed, structured, or situated within the known relationships and ordered classification systems of the digital world or the natural but strangely familiar nonetheless and, therefore, monstrous [2]. Analogous possibly to an imaginary environment filled with the mutations drawn in the chronicles of early explorers in an unknown land, next to the grotesque figures from the paintings of Hieronymus Bosch, adjoining the cyborgs from the musings of the cyber-fantasists and Syd Mead futurists, all sharing space with the autonomous robot species of the engineers and the mundane everyday sensor mechanisms that switch our lights on and off.

More specifically, as the digital realm evolves new forms of distributed computing that employ cognitive, sensory, and interactive abilities as in built feedback mechanisms, as well as predictive and collective behaviors, the overall behavioral characteristics of a digital system more closely approximate or are able to interact with the complex dynamics of both human and natural systems. As NKatherine Hayles has pointed out, the essential decision processes in complex systems have developed in ways that responsibility for decision making now requires both human and computer input. To situate this juncture as an emerging condition, Hayles points out that "the development of distributed cognitive environments in which humans and computers interact in hundreds of ways daily, often unobtrusively," [3] has transformed data and information as a flow independent of its material base, creating the possibility for the mesh of a new condition that links data and computer networks with human networks. Hayles speaks of this condition "not as a dichotomy between the real and virtual but rather as space in which the natural and the artificial are increasing entwined," [4] foreseeing the growth of what Bruno Latour calls "quasi-objects," as a multitude of hybrid objects produced by a collaboration between nature and culture. The recently published United Nations telecommunications agency ITU report, "The Internet of Things," [5] supports Latour's point of view, outlining an increasing degree of embedded computing within our everyday environments, a proliferation of computing to the extent that interactions between multiple embedded parts may in the near future outnumber actual human-computer interaction. This situation is an aspect of a ubiquitous distributed computing that will impact on notions of environment and interaction between entities within those environments whether artificial or natural.

More than being an objectified environment, second nature is also an innate acquired behavior practiced long enough to become natural, a learnt physical and emotional mode that both modifies our relation to the world and allows us to access both the natural and the digital, easily shifting our perceptual registers between the two. Second nature considered in this way may be a type of consciousness, able to touch on the emotional registers of the sublime, perhaps eliciting feelings of fear, anxiety, amazement, or elation that occur when confronted with the wild, in this capacity satisfying a base need, a necessity for the unnamable, the untamed and the not yet of this world. Mark Pauline, when interviewed by Chris Langton, outlines a consequent and necessary development in digital evolution that does not follow the technocratic tendency towards positivism, saying: "I think humans will accumulate artificial and mechanical abilities, while machines will accumulate biological intelligence. This will make the confrontation between the two even less decisive and less morally clear than it is today" [6].

The digital realm has a genotype of bits that are precisely on or off — never maybe on or maybe off — whose behaviors are generally programmed as deterministic cause and effect. This digital straightjacket defines controllable and predictable outcomes within acceptable error tolerances that all work to keep entropy at bay. To date, this imperative has predisposed the digital to a world of top-down control, one that that has lent itself to the utility of application and, in general, to cause and effect during the first half-century of digital machines. One effect of this phenomenon is that the potential of the digital as complex autonomous systems that behave in ways more akin to living things in the natural world is only now in its infancy. Kevin Kelly in *Out of Control* has argued for the need for a more autonomous swarm-like order of computing. He writes: “[A]s we unleash living forces into our created machines, we lose control of them. They acquire wildness . . .” [7]. The issue of letting go of control, relinquishing the linear thinking that regulates the digital world that Kelly outlines is as significant here as the change from Euclidean geometry to non-Euclidean geometry that led to the rapid development of innumerable new strange worlds within the field of geometry. Within the digital realm this change may signal a paradigm shift of a similar magnitude. As the digital realm begins to be applied to matters in the real world, new possibilities arise from the fusion of the natural and the digital that are only just beginning to tap into issues of bio-mimesis, autonomous behaviors and artificial ecosystems. An artificial ecology is one environment that can precisely encompass the two realms: one of artifice, a world of *daidala* and the man-made; and the other biological, a world of natural systems and processes.

Artificial Ecologies

Artificial ecology, a term drawn from artificial life theory that simulated a variety of genetic or recursive evolutions of digital entities in virtual space, is a field that is also explored by biologists and ecologists alike. However, in this context, the point of departure from the work of earlier artificial ecologists lies in the meeting of the digital world with the physical reality or the natural world.

An artificial ecology is a dynamic metabolic system contingent on material and energy flows that interrelate the various constituent parts together with the overall structure of the ecosystem. Within the man-made environment, the seeds of an approach to ecosystem design are present in early ecological writing praxis and theory [8]. The general argument made across these concepts is that an ecosystem requires a circular metabolism, using waste as food or energy, recycling material and products, reconsidering lifecycles and reuse. Accordingly, a sustainable ecosystem is one that has inbuilt mechanisms that self-regulate or manage its energy flows, its material flows, and its metabolic balances over time. The regulating mechanisms for such systems can be termed feedback loops. Feedback, for Manuel De Landa, is between “the two extremes of a complete fatalism, based on simple and linear causal relations, and a complete indeterminism. . . . The most familiar examples of non-linear causality are feedback loops, . . . forms of circular causality [that] govern the dynamical behavior of a process” [9]. Thus, to be able to synthesize or design artificial ecologies implies the integration of feedback that can develop the self-regulation of the system as a whole. This approach requires the ability to understand the system in its entirety: how it impacts on its constituent parts and how the individual parts influence or affect the system itself. As De Landa, suggests: “[A] top down analytical approach that begins with the whole and dissects it into its constituent parts (an ecosystem into species, a society into institutions), is bound to miss precisely those [synergistic] properties. In other words, analyzing a whole into parts and then attempting to model it by adding up the components will fail to capture any property that emerged from complex interactions.” [10]. In effect, to understand an environment only as a cause and effect system (top down analysis) or as an indeterminate system (bottom up) does not permit the intervention of complex interaction and is not, in essence, an ecosystem. This concept is key to the understanding of artificial ecologies, and it is only through working with both modes that an artificial ecology can be synthesized.

Ecosystems and Non-Linear Dynamics

Arthur Iberall’s [11] conceptual framework of homeokinetics assists the development of the idea of artificial ecologies. He proposes a model of society as a self-organizing ensemble of metabolic flows — of energy and material — and reservoirs of resources — knowledge, population, capacity, and excess. He suggests that we can understand the change over time in aspects of population, trade (convective flows), technological development, and social strata as a series of phase transitions that derive from the principles of phase change in thermodynamics that provides a model to explain the change of state from liquid to gas for example. Society at any given point in time might be analogously gaseous, liquid, solid, or a mix of these in Iberall’s schematic; to illustrate this point, we can consider how fluid-like social formations of hunter-gatherers eventually crystallize into stratified society or undergo further phase changes dissolving, perhaps, into more gaseous and, therefore, energetic configurations. Similarly, De Landa writes that "early societies may even have achieved a better consistency among their flows, a viscosity more in tune with their ecosystems than our own" [12]. Whilst one might argue that the generality of Iberall's schema outlined here is an over-simplification, it is useful in as much as it presents the structure of society as a complex set of transformations intrinsically related to change and defined by dynamics rather than static states. In essence, it highlights phase or state-change potentials over historical or evolutionary development that privilege step-by-step development. It emphasizes non-linear relations between entities, such that flows of a particular resource or aggregations of many smaller formations leads to certain types of societies developing and to specific chains of consequences or environmental impacts. We can find a related concept in the work of the biological systems theorist C. H. Waddington [13]. His concept of homeorhesis (similar flow) describes a system that returns to a trajectory after a disturbance, privileging the idea of continual flow, movement, exchange, and change. Waddington employed this term in distinction to the term homeostasis that describes the equilibrium of a system that returns to a static condition or state. The power of Waddington's term lies in being able to understand and begin to describe a (biological) system whose constant and normal mode is change and flow itself, meaning that the dynamic conditions of change and feedback necessarily become part of the way of thinking and working with such a system.

Digital Mimesis and Bio Mimesis

The world of artificial life, cyborgs, and cybernetics owes much to *daidala*. *Daidala*, a type of artifice from the ancient Greek times, employed a type of bio-mimesis, a borrowing from the natural world to remake the natural order in objects composed of inanimate matter that mimicked life itself. Such objects were imbued with a life-like appearance, capable of dangerous illusions so that things could appear to be what they were not. The creation and manifestation of such effects in objects can be seen to be subverting or challenging the order of the gods. In this way *daidala* represent a fundamental act of mimesis. It is as if they "possess mysterious powers . . . [for example] jewels, are endowed with *charits* (charisma) and thus with *kalos* (beauty) and *amalga* (festive religious exaltation)" [14]. Most significantly, the point of *daidala* is that of "enabling inanimate matter to become magically alive, of reproducing life rather than representing it" [15]. It is through the hand of the demiurge that these qualities are brought into being and through this process that such animate qualities can appear and be embodied: "[I]n Homer techne, particularly metalsmithing, carpentry, and weaving, is the know-how of the *demiourgoi*, and it is not differentiated from the act of magic which, like Prometheus, taps the power of the gods. Controlling, often dangerously, the order of the world, the demiurge creates wondrous objects or magical effects. Technical action depends upon the same kind of intelligence as *metis* (magic), a propitiatory power or cleverness in overcoming disorder" [16].

As we begin to imbue our digital world with the capacity to sense, to react, and to exist within artificial ecologies, digital entities begin to take on *daidala*-like qualities, ever closer to life-like entities and exhibiting life-like behaviors. The embodiment within digital entities of a form of mimesis asks the question of what type of species could inhabit an artificial ecology. Can there be, for example, a form of digital mimesis that draws from and subverts the logic of the digital world, leading to various types of digital species, entities able to speak and react to other digital entities, existing as some type of artificial ecology, in a complex series of balances and energy, flows between digital entities where internal and external data, information, light, sound, bits, heat, and matter constitute the food web of the ecosystem — an actualization of the potentials of distributed cognitive computing that Hayles and Kelly write of?

Play in the System

In 2000, I established the postgraduate research laboratory and studio A+URL, [17] building on a number of years of experimental studio teaching at KTH Architecture School investigating the impacts of various types of media on spatial thinking. The point of departure of A+URL was to understand the man-made environment as a dynamic system and to research issues of urban scale metabolic systems and artificial ecologies. As a research laboratory its agenda was to develop a body of proof of concept hands-on applications that test out hypotheses as applied research. This research was more culturally driven than scientifically determined and was not necessarily predicated on use, function, or direct application. Whilst not necessarily traditionally academic, the work aimed at a synergistic or synthetic approach typical of studio-based approaches. As a parallel endeavor a more serious research focus allowed for dialogue and potential collaboration to be initiated with technology companies such as Telia, Ericsson, and the Interactive Institute in Stockholm.

The year-long program asked postgraduate participants, in small groups, to develop their own research agendas within the program framework around issues, such as: Can there be symbiosis between artificial and natural systems? Can we imagine possible metabolic (non-linear systems) that can work between natural and artificial environments? Inputs provided technology and design workshops and seminars that focused on metabolic systems, emergent spatial formations, and new organizational patterns. The program utilized ideas of applied research as a mode of development, privileging process over product in a hands-on prototype laboratory. New modes of working were tested and developed through unconventional experimentation within this milieu.

The core part of the work involved making interactive physical and digital installations that link natural phenomena to the digital world, conceived as strange kinds of artificial ecologies. By synthesizing ecosystem principles with digital technologies, it is possible to construct simple types of artificial ecologies in which the system senses, reacts, and continually adjusts according to external and internal conditions. These principles can be modulated through sensors and translated into digital means and also into various behaviors. It can also be extended as a means to include human inputs and actions within the system. Such possibilities have been aided by technological change that allows the formerly discrete virtual digital world to begin to talk to the external world. In recent years, the availability of low-end microprocessors, the readily available technologies of sensors and servomotors, and available miniaturization have made it increasingly easy to construct things and entities with inbuilt feedback and sensing abilities [18].

Initially, participants investigated, modeled, and derived hands-on principles and understanding from 'natural' ecosystems as a form of bio-mimesis or bio-logic. Issues investigated included swarm behavior, phase transitions in ice, Aurora Borealis, static electricity, photosynthesis, glacier formation, and bioluminescence. The intention of this stage was to enable participants to understand ecosystem as process and to be able to extract, model, and manipulate some of the aspects they uncovered in their research. One group investigating the Northern Lights made fog clouds and studied their dispersal in the environment. Another group interested in static electricity wired up a three level building to see what potential electricity could be generated, later making a device to harvest static electricity from rainfall.

Secondly, the program asked participants to synthesize their principles into small-scale interactive ‘ecologies’, assemblages and systems that used feedback. Through a series of prototypes, made from fabricated parts, found objects, washing machines, plotter parts and fruit, the final dynamic models employed programmable technology of microprocessors [19], coupled with sensors and servo motors as a means to generate inputs, outputs, and feedback. Each ecology is, therefore, an elaborate and artificial environment that operates according to both internal and external inputs and the mediation of these. This environment embodies some aspects of ecosystems in its dynamic and cyclic system and uses the principles of transformation of energy as an integral part of its functioning. Three examples illustrate some of the outcomes of the work; further explanation can be found on the A+URL website listed in the endnotes.

The Fog Table mimicked the Aurora Borealis' plasma clouds by moving a cloud of fog according to changes in a magnetic field. Such that the magnetic field of a cell phone or any electronic device had the effect of moving the fog cloud captured in a table, employing the principles of an enormous scaled natural phenomenon within the domesticated situation of a piece of furniture and the daily activities of picking up a cell phone. Figure 1 (see page 1) shows the fog table in operation with the moving cloud of fog visible within a Plexiglas tabletop; the magnetometer is shown as a detail on the right hand side of the image.

Figure 2: Singing Lemons Instrument: Light sensitive organic electronic music machine

Singing Lemons Instrument, derived from the earlier investigation of photosynthesis, was a musical instrument that drew its energy from the galvanic potentials of the lemon used as a battery that responded to people's movement and light. People's interactions triggered a light sensor in front of the apparatus, activating small single note buzzers by moving electrodes into or out of the lemon, thereby playing the instrument. The depth of the electrodes in the lemons determined the volume of the note played as the acid concentrations inside the lemon vary, eventually dying as the galvanic power of the lemons was diminished. Figure 2 presents left to right a detail of the singing lemons, its interaction through waving or casting a shadow and a view of the whole apparatus.

The Terra-iser was derived from the study of glaciers as landscape generators and as large-scale information machines that are continually added to on top whist melting underneath. It constructed an ever-changing landscape according to the movements of people around its orbit, vacuuming up small clay balls and sorting or randomizing them as it deposited the clay balls. It was fabricated from hacked plotter track assemblies, washing machine parts, and vacuum cleaner

Figure 3: The Terra-iser: Landscape randomizing and sorting machine.

Figure 3 shows left to right two views of *The Terra-iser*, the sorting mechanism is the vacuum plastic carapace. The view on the right is of *The Terra-iser* in operation on its landscape.

Conclusion
Significantly, the artificial ecologies developed embody a sense of play that remains open and active. Although technology-driven and machine-like, they are without utility value or useful function. The play in the machine here relates to the non-linear causality that De Landa mentions, potentially acting as a bridge between different environments, scales, and entities. Play in the machine, therefore, avoids the technocratic mechanistic realm of cause and effect (the functional machine, the factory robot, the tractor, or the plough). It does this through becoming imbued with sensory capabilities and responses (sensors) and through processes of feedback. It is enabled with characteristics (character) that are not only contingent on simple cause and effect (input and output) but take into account effects from wider environments. There are, of course, limitations that the digital world meets in modeling non-linear systems. Digital cause and effect is an undeniable parameter as behaviors, actions, and interactivity, in general, need to be programmed and may in some way be predetermined by intrinsic coding. The aspects of play in the artificial ecologies, however, bypasses the fundamental technological limitations and allows for the unexpected in the lemon powered musical instruments that operate on photosynthesis principles in which code becomes translated through bio-logic into strange kinds of action and feedback. The unpredictability of outcome, freed from constraints of orthodoxy, is evidence of a real desire to play, transgress, and make hybrids that link the digital and the natural worlds.

Acknowledgements
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References and Notes
1. Victor Turner, "Betwixt and Between in The Liminal Period", *The Forest of Symbols, Aspects of Ndembu Ritual* (Cornell University Press, 1967).

2. See Turner [1] on the idea of the monstrous hybrid. Julia Kristeva and Mary Douglas write similarly around the issue of the fear of category confusion and pollution.

3. N. Katherine Hayles, *An interview/dialogue with Albert Borgmann and N. Katherine Hayles on humans and machines*, http://www.press.uchicago.edu/Misc/Chicago

/borghayl.html.

4. See Hayles [3]

5. See Hayles [3]

6. Kevin Kelly, *Out of Control* (Addison Wesley Press, 1994) p. 54.

7. See Kelly [3], p. 4.

8. Ian McHarg in *Design with Nature* (Natural History Press, 1971), argues that an understanding of ecology necessarily invokes a cycle of entropy and negentropy in which energy is currency, circulating between inventories of matter, culture, and gene pools. The concept of energy flow as a necessary component of a sustainable environment is continued through James Lovelock's Gaia concepts, the ecological footprint concepts of William Rees in *Our Ecological Footprint* (New Society, 1996) or Herbert Giradet's concepts for a circular metabolism or closed loop system for cities in *The GAIA Atlas of Cities* (GAIA Books, 1996).

9. Manuel de Landa, *A Thousand Years of Nonlinear History* (Swerve Editions/Zone Books, 1997) pp. 17-18.

10. De Landa, "Markets, Antimarkets and Network Economics", in *Found Object*, Vol. 8, pp. 53-54 (1996).

11. See Arthur Iberall, *Towards A General Science of Viable Systems* (McGraw-Hill Book Company, 1972).

12. De Landa, "Nonorganic Life", in Jonathan Crary and Sandford Kwinter (eds.) *Zone 6: Incorporations*, (Zone Books, 1992) p. 154. It is significant to note that these phases are determined from the interaction of millions of small flows and the system state itself — in other words, from the interactions of the micro and macroscopic.

13. See C.H. Waddington (ed.), "Towards a Theoretical Biology" in *Vol. 1: Prolegomena* (Edinburgh U.P., 1968). Waddington's concept of homeorhesis relates to the concepts of an epigenetic landscape.

14. Alberto Perez Gomez, "Daidala", in *AA Files*, Vol. 10 pp. 49-51 (1985).

15. See Perez Gomez p. 50.

16. See Perez Gomez p. 51.

17. Architecture and Urban Research Laboratory, http://www.arch.kth.se/a-url/description.htm, was co-established by the author with Ana Betancour in The Royal Institute of Technology, Stockholm, Sweden in 2000. For further examples of the work, refer to http://www.arch.kth.se/a-url/interspace.htm. *Interspace*, an exhibition of the work was held at the Kulturhus in Stockholm. A catalogue of the same name was published.

18. See Neil Gershenfeld, *Fab: The Coming Revolution on Your Desktop — From Personal Computers To Personal Fabrication* (Basic Books, 2005). Gershenfeld, uses similar technologies to enable hands-on making of microprocessor embedded objects. He writes of a shift of fabrication from mass production to personal fabrication and customization, an enabling revolution that both allows but also argues for the need for a hands-on literacy applicable for today's world.

19. Basic Stamp II microprocessors, breadboard circuits, and interactive design technologies were assisted in three one-day workshops by Dr. Jon Rogers.

Author Biography

Peter Hasdell is an architect and academic. He studied film theory and computer engineering before graduating in architecture from University of Sydney. Post-graduate studies completed at the Architectural Association (London), Ph.D in process in Stockholm. He has worked as an architect and artist on both theoretical and actual projects in a number of countries for 16 years.

He has taught architecture, design and technology in Europe and North America, and has held positions at the Bartlett School London (UCL), The Berlage Institute in Amsterdam and at KTH Architecture School in Stockholm. His academic work has included research, lecturing and teaching at various institutions in different countries at undergraduate level, postgraduate level and post professional level. In Stockholm he was recently Associate Professor/programme founder/director of the innovative research studio Architecture and Urban Research Laboratory investigating the mediated city, urban scale metabolic systems and artificial ecologies.

He is currently Professor of Architectural Technology at the University of Manitoba. His research work presently investigates metabolic systems and interactive technologies with a focus on 'artificial ecologies' and issues of sustainability. He has been a member of various research institutes including Chora Institute of Urbanism and Architecture in London.

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