Keynote

Abstract

Computational Creativity | A Multi-perspective Approach

Key words: computational creativity, Cybernetics, Gordon Pask, Recombinant Poetics, Recombinant Informatics, learning systems, multi-perspective approach. Biological Computer Laboratory, Heinz von Foerester

In this talk I will discuss Computational Creativity | A multi-perspective Approach. Building on historical references to cybernetics and artificial intelligence, I will also introduce my more recent collaborative research with Otto Rössler on Neosentience, which holds great potential for the future of creativity involving robotics and learning systems. These ideas will be further elaborated and amplified with concrete examples from my artistic practice, including The Many Senses Engine (with Todd Berreth), on display at the festival exhibition.

Computational Creativity | A Multi-perspective Approach

Margaret Boden in her book *Creativity and Art* defines creativity as "the ability to come up with ideas or artifacts that are new, surprising, and valuable."[1] Ada Lovelace, the first computer programmer early on saw hypothetical creative potentials for computational operations:

> The Analytical Engine is an embodying of the science of operations, constructed with particular reference to abstract number as the subject of those operations... Again, it [The Analytical Engine emphasis the author] might act upon other things beside *number* were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations, and which should be also susceptible of adaptions to the action of the operating notation and mechanism of the engine. Supposing for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expressions and adaptions, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent... It may be desirable to explain, that by the word operation, we mean any process which alters the relation of two or more things, be this relation of what kind it may. This is the most general definition and would include all subjects in the universe.[2]

Lovelace was articulating the creative potentials of the computer in terms of composing music, and simultaneously suggesting a particular principle that was much more universal in 1843!

In my teaching, in my artistic practice, and in my research, I always discuss the computer as an open system that can be creatively approached in many different ways. I discuss the potentials of the computer in

extremely broad terms that at this time are only limited by human imagination — if one can logically articulate a particular kind of system and functionality, then one can potentially develop that system or aspects of that system, or alternately "chip away" at exploring its facilitation as a long-term goal.

The now deceased Stephen Wilson discussed a series of relevant creative computational works in his book *Information Arts*. [34]Along with the book Wilson developed a website with an incredibly elaborate set of links that are valuable in teaching to this day. The titles of these links also point to a vast set of computational approaches to the creative use of computers (in the hundreds). Many of these examples explore creative approaches to interface as well as create unique aesthetic "artifacts" through their "code authored" functionalities.

In 1989, Alan Kay, a computer scientist interested in interface design discussed *enactive* approaches to creativity. In "User Interface: A Personal View" Kay states:

> … Let me argue that the actual dawn of user interface design first happened when computer designers finally noticed, not just that end users had functioning minds, but that a better understanding of how those minds worked would completely shift the paradigm of interaction.[5]

The concept of reverse engineering thought processes becomes central. Lev Mannovich discusses Kay in his book *Software Takes Command*:

> Kay… drew on a number of studies on creativity in math, science, music, art and other areas which suggested that initial creative work is done mostly in iconic mentality and also in enactive. This provided additional motivation for the idea that if computers were to function as a dynamic medium for learning and creativity they should allow their users to think not only through symbols but also through actions and images.[6]

Here we must point at the interface, not as the "surface" of interaction but as the entire set of loops of action, interaction, and intra-action that can be initially broken down into input, functionality, and output, with an interactant actively participating within this set of cybernetic loops. I see this happening on two different levels simultaneously – on a meaning level, where the programmer authors a particular set of potential relationships between code and the physical world, and the level of physics, where an outcome of computation is brought about though a passage-flow of energy, system functionality, interaction, and change.

Alternately, one can author stand-alone systems that just run, carrying out a set of programmed decisions to form an artifact, be it (still) screen-based images; physical (as in rapid prototyping or the printing of images); behavioral (as in robotics) or the bringing about changes in a ecological or architectural situation; or over time as in digital time-based media output. How can we create computers that build up knowledge about the world through multi-modal sensing and learning, that make their own creative decisions, and why would we want to do this? I would say – displacement illuminates placement…

I have been looking closely at computational creativity for some time. I early on wrote a paper entitled "Emergent Constructions: Re-embodied Intelligence Within Recombinant Poetic Networks". I presented this in the conference *Consciousness Reframed* in 1997 where I discussed the concept:

> Re-embodied intelligence can be defined as the translation of chosen media elements and/or processes into a symbolic language enabling those elements and processes to become part of an operative computer-mediated system. If we think about the creative processes artists go through in the making of non-computer-mediated works of art, is there a way to model these processes and re-embody them within a computer mediated environment? Along with the transformation of traditional media: photography, collage, concrete poetry, music etc. into the digital domain, how can artists generate models which are entirely driven by the new potentials of recombinant image, sound and text space [as well as explore media-behaviors, emphasis the author] inherent to the computer?[7]

In this case I wasn't talking about an autonomous computer system but a system designed for human/computer interaction. My PhD on *Recombinant Poetics* pragmatically explored my generative world constructing system, with programming by Gideon May entitled *The World Generator / The Engine of Desire.* The subtitle of my thesis is *Emergent Meaning as Examined and Explored Within a Specific Generative Virtual Environment.*[8] This artwork enabled users of the system to "create" virtual worlds in real time, as well as explore high-level generative computational processes. It presented different examples of computational creativity --- one example was the generation of aesthetic virtual worlds at the "press of a button", based on aesthetic potentials authored into the system. The second empowered the user to bring their own sense of aesthetics and creativity to bear in conjunction with those authored potentials. The "world generating" was algorithmically facilitated, and later led to the idea of autonomous engines that created visual worlds in a generative manner without direct human interaction. Here the computer set in motion particular creative/aesthetic algorithmic approaches in a recursive manner.

For me *The World Generator* was a means of pointing (in the sense of Witgenstein[9]) at creative thought processes and meaning production, though the experiential exploration of a combinatoric generative system. Instead of writing about creativity and meaning, this enabled one to experience meaning arise and change through dynamic interaction with the computational system. William Clancey in his book *Situated Cognition: On Human Knowledge and Computer Representations* states:

> In short, situated cognition is the study of how human knowledge develops as a means of coordinating activity *within activity itself.* This means that feedback—occurring internally and with the environment over time—is of paramount importance. Knowledge therefore has a dynamic aspect in both formation and content. This shift in perspective from knowledge as *stored artifact* to knowledge as *constructed capability-in-action* is inspiring a new generation of cyberneticists in the fields of situated robotics, ecological psychology, and computational neuroscience.[10]

Thus we ask, how observing the history of dynamic interactions with environment can inform new approaches to interface design and related computational creativity?

Margaret Boden in the book *Creativity and Art* speaks about "combinational creativity" in part as the

generation of ”unfamiliar combinations of familiar ideas.”[11] She goes on to say that combinational creativity “underlies most spontaneous jokes and wordplay, and is a key source of poetic / literary imagery and visual collage.”[12]

There are many questions related to whether computers can be creative in themselves. Boden states, in relation to the difficult questions of computational “consciousness, intentionality, and the role of ‘brain-stuff’ and/or embodilment”:

> Since the notoriously controversial problems remain unsolved, I no where claim that computers are “really” creative. If and when I mention creativity in computers I am really asking what aesthetically interesting results can computers, generate and how? And just what might lead someone to suggest that a particular computer system is creative or that its functioning is somehow similar to creativity in human beings.[13]

Bowden leaves the question of “real” computer creativity open. Such autonomous creativity is the production of a system that might become aware of its decisions on a meta-level of understanding, incorporating multi-modal sensing, short, and long term memory, as well as “learned” creative values.

Human creativity is a very special activity. We might first try to unpack creative processes through self-observation and the observation of the practices of others. What is it that I do when I am being creative? How does this become operative in terms of thought processes? Is this creative thinking available to me through introspection? ‘Mindful awareness’ practices are discussed in the *The Embodied Mind: Cognitive Science and Human Experience* by Varela, Thompson and Rosch.[14] They state:

> Its purpose is to become mindful, to experience what one’s mind is doing as it does it, to be present with one’s mind. What relevance does this have to cognitive science? We believe that if cognitive science is to include human experience, it must have some method of exploring and knowing what human experience is. (Varela, Thompson, and Rosch, 1996, p.23)[15]

Yet, which biological processes are contributing to creative practice, functioning beneath the surface of thought – outside of the limits of our introspection? How do emotions inform creative practice? It is clear that along with introspection, one draws on a series of observations of differing processes over time to inform creative production. Here I would focus on the nature of multi-modal patterning that is being constantly reinforced through similar but different experiences. In this sense we might need to “bring-up” our autonomous learning system like we would a child, enabling “this entity” to develop an approach to patterning informed by multi-modal sensing systems, the building up of context awareness, enculturation, and extensive linguistic framing.

I can observe others’ creative processes and logically, through deduction, inference, and abduction begin to expand my understanding of creativity through these alternate perspectives. Many forms of situational observation can be draw upon. These pattern flows[16] of observational processes all become enfolded, or can pop to the surface of thought, to in part inform new creative activities. One wonders how many creative works and/or creative processes one observes in a lifetime of accretive observation? We both learn to be

creative and are endowed with creative potentials that are part of our being. We can draw on aspects of self-knowledge to author systems where self-reflection, meta-levels and differing qualities of abstraction inform the ongoing development of computational practices. John Supko calls this "parameterization," or abstracting qualities of particular parameters so they can become operative in a computational system.

The historical study of Cybernetics, presents an interdisciplinary set of approaches to "Observing Systems"[17] This title by von Foerster can be read in a bi-directional manner. Observing Systems or Observing Systems. Thus early on, Cyberneticians were studying machines in terms of the re-embodiment of thinking processes as well as deriving appropriate situated behavior. Von Foerester also calls cognition, computation, further complicating the bi-directional stream of humans learning from computers and the design of computers being learned by studying humans…

In defining cybernetics, Ross Ashby points out that it is, "essentially functional and behaviouristic"[18]:

> Many a book has borne the title "Theory of Machines", but it usually contains information about mechanical things, about levers and cogs. Cybernetics, too, is a "theory of machines", but it treats, not things but ways of behaving. It does not ask "what is this thing?" but "what does it do?

So we ask, what is at operation in us when we are behaving in a creative manner (thinking back to Lovelace's initial comment about computation and operationality)? Central to the invention of creative and meta-creative systems is the reverse engineering and subsequent modeling of human creative processes --- of addressing creativity as a biological "functionality" from many different operational or behavior-related perspectives. The next step is to apply these models to the design of differing machinic, proto-biological, robotic, and/or cyborgian systems. In terms of central pre-cursors, Gordon Pask comes to mind. Pask was a scientist interested in learning systems, "Teaching Machines", "Conversation Theory" (conversations leading to learning), in Generative Architecture, in Interactive Art, and in biologically inspired Chemical Computers among other things. The work of Pask has provided great historical stimulus to studies in computational creativity.

The topic of computational creativity was often returned to in a decade long "conversation" between Seaman and Otto Rössler discussed below, concerning Neosentience (Seaman's coin) – or the long-term creation of an autonomous "creative" robotic learning system. Inspired in part by Pask's thought, in *An Appoach to Cybernetics* where he wrote:

> This book is not for the engineer content with hardware, nor for the biologist uneasy outside his specialty; for it depicts that miscegenation of Art and Science which begets inanimate objects that behave like living systems. They regulate themselves and survive: They adapt and they compute: They invent. They co-operate and they compete. Naturally they evolve rapidly.[19]

He appears to be pointing to the tenets of Artificial Life, long before the field was articulated in depth, in the book *Artificial life: an overview* By Christopher Langton.[20] In terms of discussing cybernetics and evolutionary approaches, Pask layed out the following picture, perhaps in part discussing

activity at the Biological Computer Laboratory directed by von Foerster:

> A cybernetic laboratory has a varied worksheet—concept formation in organized groups, teaching machines, brain models, and chemical computers for use in a cybernetic factory. As pure scientists we are concerned with brain-like artifacts, with evaluation, growth and development; with the process of thinking and getting to know about the world. Wearing the hat of applied science, we aim to create what Boulanger, in his presidential address to the International Association of Cybernetics, called the instruments of a new industrial revolution—control mechanisms that lay their own plans.[21]

In the text "Gordon Pask: Cybernetic Polymath," María Fernández points out that "Pask developed his own unique flavor of cybernetics, which (she contends) was deeply informed by his intellectual interest and practice in the arts. With his theoretical writings he contributed to a diversity of fields including cybernetics, cognitive science, psychology, education, ethics, and sociology."[22] His seminal artworks, which are discussed in her text, are early examples exploring aspects of computational creativity, *The Colloquy of Mobiles* (1968), and *Musicolour* (1953-55) and even perhaps autonomous creativity (in the latter work) in the fact that it might "steer" (Cybernetics draws from the root word kubernetes or "steersman") the musicians to change their approach to intra-active music production as it relates to a dynamic lighting system. The show "Cybernetic Serendipity" included Pask and was one of the first venues to highlight the creative use of computers.[23] [24]Fernandez goes on to say:

> Pask's primary theoretical contribution to the arts was his concept of "aesthetically potent environments," anchored in his understanding of the work of art as a system that evolved either independently or in interaction with a participant. These ideas, directly informed by cybernetics, entailed propositions involving interactivity, organization, intelligence, communication, learning and agency.[25]

To my mind these attributes contribute in the production of a machinic creativity — to the ultimate goal of creating the capacitiy to function creativly in an autonomous robotic system. Peter Cariani in *Computers and Creativity* [26] discusses Pask's "Organic Analogues to the Growth of a Concept". He states:

> The most striking example of a creative emergent device is an adaptive self-constructing electrochemical assemblage that was conceived and fabricated by the brilliant and eccentric British cybernetician Gordon Pask in the late 1950s. Pask demonstrated his device at the *Mechanisation of Thought Processes* conference in London in 1958 and described it in a paper provocatively entitled "Organic Analogues to the Growth of a Concept."[27]

Work like this was central to the embodied/embedded approach to Computer Science. Such an approach looks in part to the body and/or the abstraction of sensing systems as ways to build up knowledge about the world. The BCL has been in part been left out of the common history of Computer Science. The book titled *An Unfinished Revolution? Heinz von Foerster and the Biological Computer Laboratory* by Müller and Müller, goes into to depth about the incredible "creative" research that went on there. In terms of the "autonomous approach" to creativity, Cariani has discussed Ashby:

> All attempts at artificial intelligence inevitably confront what W. Ross Ashby called Descartes' Dictum: how can a designer create a device that outperforms the designer him/herself?[28] Ultimately it is a problem of specification: if the designer specifies all of the parts of the device and what it will do under all circumstances, it will not do any better than its maker. We know, however, that such devices can be made, and indeed they have been made. We now have chess playing devices which can outplay all but the very best human grandmasters, playing far better than their creators. What allows them to outperform their designers? As Ashby noted, in order to achieve better performance over its initial specification, a device must be informationally open, capable of interacting with the world independently of its designer. The device must have some degree of epistemic autonomy in order to improve itself, but epistemic autonomy is not achievable without some degree of structural autonomy.[29]

The deep question is, how can we create systems that define a sense of epistemics for themselves via a history of situated knowledge that is built up contextually over time via learning?

A System of Systems

Historical studies into the body and the brain sciences in particular usually take a focused approach to a very specific part of a biological system. Yet, when we take the environment/body/mind/brain and study it as a holistic system, a new series of questions opens out, exploring the vast operative functionality of this 'system of systems'. In studying the functionality of the body, abstracting qualities of this functionality, and applying this knowledge to computational practices through bio-mimetics and bio-abstraction, we can work toward creating new systems and defining new approaches to computation and interface. Seaman's papers *The Engine of Engines, Toward a Computational Ecology*[30], and his paper *Neosentience and the Abstraction of Abstraction*, both explore this topic at length.[31]

Here the historical study of Cybernetics and Second Order Cybernetics becomes central. Norbert Weiner's seminal 1948 book, *Cybernetics or Communication and Control in the Animal and the Machine*[32], opened up a fertile interdisciplinary research arena. Weiner was highly interested in a multi-perspective approach to knowledge production, yet also wrote about its problematics:

> It is these boundary regions which offer the richest opportunities to the qualified investigator. They are at the same time the most refractory to the accepted techniques of mass attack and the division of labor…If a physiologist who knows no mathematics works together with a mathematician who knows no physiology, the one will be unable to state his problem in terms that the other can manipulate, and the second will be unable to put the answers in any form that the first can understand… a proper exploration of these blank spaces on the map of science could only be made by a team of scientists, each a specialist in his own field but each possessing a thoroughly sound and trained acquaintance with the fields of his neighbors; all in the habit of working together, of knowing one another's intellectual customs, and of recognizing the significance of a colleague's new suggestion before it has taken on a full formal expression.[33]

How can we begin to educate researchers who seek to explore computational creativity on a number of different levels? In terms of the highest levels of creativity and meta-creativity, how can contemporary individuals as well as teams of researchers take on a holistic approach to the body as a system of systems?

Thus a broad range of creative explorations run the gamut from tool creation leading to differing forms of computational artefacts; to at the highest level, autonomous robotic systems, perhaps exhibiting creativity entirely of their own ilk.

In 1960 a paper by J. C. R. Linklider, discussed the notion of *Man-Computer Symbiosis*.[34]

> The hope is that, in not too many years, human brains and computing machines will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today. [35]

He went on to say that "intellectually"… this would be "the most creative and exciting [period] in the history of mankind."[36]

McCormack and d"Inverno in their book *Computers and Creativity* provide an excellent compendium of creative computational practices and the concepts that surround them. They speak to the fact that computers are machines that present a "radical new potential for extending creativity."[37] McCormack, working somewhat in the modality that Linklider articulates in his text above, discusses one example of A-life as a particular "creative" methodology via *The Interactive Genetic Algorithm*:

> The (IGA)[38] for example, is an artificial evolutionary system in which a user selectively "breeds" aesthetic artefacts of some sort (see (Takagi; 2001)[39] for a survey), or manipulates an evolutionary outcome via a user-defined fitness function (e.g., (Sims; 1994[40]; Bentley; 1999a[41])). The IGA can only possibly achieve adaptive creativity by being coupled with a human user, in a generate-and-test cycle. However, it allows the user to explore new patterns or behaviours beyond those he would have devised using imagination or existing forms of experimentation (Bentley; 1999b[42]). As such, it is not autonomous, and yet it is active and participatory, grounded in an external system of value through a human user.[43]

Thus along with studying the body, the abstraction of Darwinesque biological adaptation can also be employed in the service of creative computational endeavors. Yet, the hard question is as humans, how do we build up the potentials for facilitating creative practice both biologically and in a social and cultural sense, and in particular how do we come to have notions of "value" --- what makes an artwork, work?

I encourage everyone, and in particular my students to think "large" about their initial approach to the design and facilitation of new computational systems, and perhaps the long-term creation of autonomous creative systems – and/or what might be called meta-creative systems. Working toward a near impossible goal tends to release new ideas that are equally employable along the way… Of course attempting to observe what is at operation in human creativity comes into play in the invention of creative systems — systems that are emergent in nature. In *Understanding Understanding*[44] the title of a book by Heinz von Foerster,[45] he discusses the notion of cognition as "computing a reality," thus, suggesting that creativity as a cognitive process is our ability to create new realities in part via "recursive processes of computation". Yet he only touches on the artistic/creative subject via a question, he asks: "What are the consequences of this in ethics

and aesthetics"?[46] The difficulty is this, not all of our internal "computational processes" can be witnessed through self-reflection in such a way that we can reverse engineer them. We must take a multi-perspective approach to the observation of creative processes, to help reveal them through "informed" juxtaposition of research drawn from multiple fields, and work toward creating new hybrid fields of research in an ongoing manner drawing from 'recombinant informatic' processes (Seaman's Coin).

In *Computing Nature – A Network of Networks of Concurrent Information Processes* by Gordana Dodig Crnkovic and Raffaela Giovagnoli, They discuss new approaches to natural and unconventional computation:

> If we want to construct such self-sustained, intelligent, adaptive computers capable of not only following instructions but even creating new algorithms, we might need to take the boredom and joy and other human characteristics [read emotional] into our broader model of computing. Those are qualities that may fuel creativity, even though they act as disturbance when performing lengthy mechanical calculations. Nature uses both mechanical and creative computing in cognitive agents.[47]

Dale Purves, Neuroscientist, suggests in conversation with Seaman, "the fundamental principle that underlies brain function remains to be agreed upon." How can we proceed to creatively draw from bio-functionality without such an overarching set of principles? At the moment many advances are being made by separate researchers, perhaps in each case defining a set of important operative 'articulated functionalities'. In terms of bio-mimetics and bio-abstraction. Many of these research areas can be drawn upon productively. Witness the biologically inspired sensing systems that are now included in many phones — haptics, touch sensitivity, voice recognition, camera systems, microphones, etc. or the high level "brute force" computational behaviors of IBM's "Watson" on Jeopardy[48] enabling it to "win" a particular social and cultural game. I believe the productive future of new forms of creativity research will be more in line with how researchers from different fields contribute toward the creation of more holistic computational systems, by creating "intra-systems" and 'meta-intra-systems', systems that "talk" to each other. This might be called a new science of interface ecologies.[49] The science of the interface[50] symposium held at the ZKM on the occasion of Otto Rössler's 60th birthday discussed "Interfaciology":

> Because the broad implications of interfaciology (in Rössler's term) extend across disciplines, we are proposing a symposium that looks as much at physical, biological, mathematical, and engineering aspects of the interface as it does the historical, philosophical, social, and artistic interpretations that are enveloped in the emerging discourses of techno-culture. This would suggest that areas such as cognitive systems, complex systems theory, and the brain sciences, will be as relevant to the discussion as cinema, television, media art, theories of representation and spectatorship in experiential conditions driven less by singular states and more by transformations.[51]

Autonomous creative computational systems that learn and apply their learned aesthetic knowledge are closer to science fiction at this point in time --- witness the "Creative" computational system working in the style of Joseph Cornell in William Gibson's book "Count Zero"(1986). Yet, science fiction can also stimulate thought about the limits of approaching a particular vision, and perhaps in the long run such a project of

autonomous creative computers can be brought to fruition, as discussed in *The Singularity is Near* by Ray Kurzweil[52]. In terms of Neosentience[53], my ongoing research with scientist Otto Rössler, we might now begin to discuss the notion of a machinic imagination. How might autonomous learning systems come to learn to “imagine” to inform their own future creations? How does one “author” autonomous imagining?

Seaman and Rössler’s book — *Neosentience* | *The Benevolence Engine* is a nonlinear compendium of different references and approaches to the creation of an autonomous robotic learning system. The book is written in an interesting form - there are hundreds of short chapters that include a title, a section by us (sometimes a paragraph or full page) and a relevant quote, either from or about the person that we are interested in; a section derived from one of our past papers; and/or a textual section that is contemporary in nature. The book is a highly transdisciplinary non-linear manuscript drawing from many research fields. The book also includes quotes from particular philosophers and historians. It also points to particular works of art, the history of science, and science fiction as precursors to our undertaking. The Foreword was written by Siegfried Zielinski – entitled Believing Machines (another bi-directional play on words).

Neosentience, is a potentially new branch of scientific and poetic inquiry related to artificial intelligence. The concept of Neosentience was first suggested in a paper by Seaman as part of a new embodied robotic paradigm, arising out of ongoing theoretical research with Otto E. Rössler. Seaman, artist-researcher and Rössler, theoretical biologist and physicist, have been examining the potential of generating an intelligent, embodied, multimodal sensing and computational robotic system. Although related to artificial intelligence the goal of this system is the creation of an entity exhibiting a new form of sentience. 'Sentience' is not yet used in the formal languages of either cognitive science or artificial intelligence. Two related approaches are (1) the generation of artificial minds via parallel processing, in a robotic system; (2) an alternative approach is the generation of an electrochemical computer as a robotic system. Biomimetics, along with state-of-the-art computer visualization is employed. The electrochemical paradigm has a complexity that exceeds standard computational means. The scientific and the poetic elements of the project are motivated by human sentience. This transdisciplinary approach necessitates different forms of inquiry to inform this project such as cognitive science including psychology, education/learning, neuroscience, linguistics, philosophy, anthropology, biology and the arts, among other fields. This research is one example of a many-perspective approach to creativity and knowledge production. In the book I describe this as an example of Recombinant Informatics. The idea is that by bridging the concepts in the micro-chapters, new areas of research are suggested. In this way, the Neosentinece book becomes the seed to an approach of authoring-imagining (discussed above), in this case inspiring human imagining!

The notion of building a model for a Neosentient computer and related robotic system is both an exciting and daunting task. In order to model and ultimately build such a device one seeks to borrow important operative concepts and processes from the body and re-understand them in the context of a mechanism that is not human in nature. Seaman and Rössler have articulated the following 'Operative’ Definition of Neosentience - We consider a neosentient robotic entity to be a system that could exhibit well defined functionalities: It learns; It intelligently navigates; It interacts via natural language; It generates simulations of behavior (it 'thinks' about potential behaviors) before acting in physical space; It is creative in

some manner; It comes to have a deep situated knowledge of context through multi-modal sensing; It displays mirror competence. The system employs a set of force fields that simulate emotions. We have entitled this entity *The Benevolence Engine*. The interfunctionality is complex enough to operationally mimic human sentience. Benevolence can in principle arise in the interaction of two such systems.

Neosentient Design

A number of creative processes become involved in defining Neosentient Design and Aesthetics[54]. Seaman and Rössler defined an initial flow diagram outlining the workings of a Neosentient system. Yet, it is clear that in order to actually build such a device the cooperation of many different researchers from different fields will need to be drawn upon.

Neo-neuroesthetics

One "operative" perspective is drawn from Neuroesthethics exploring how we might design and author computational systems that re-embody relevant thought mechanisms found in the human. In particular this has been explored in the realm of artificial intelligence in terms of the historical training of neural nets to make particular machinic aesthetic judgments.[55]

Neosentience seeks to articulate a new computational paradigm and thus a particular kind of aesthetics would potentially arise as a result of the functionality of the system. This approach seeks to generate a meta-level discourse related to Neural Aesthetics in that it seeks to re-embody knowledge related to a broad set of "human" aesthetic understandings as framed in part by neuroscience, by employing them in multiple ways in the service of the generation of a model for an autonomous Neosentient robotic entity.[56] Central to both the science and poetics of neosentience is to try to abstract the salient qualities of the human self that contribute to the arising of sentience— creativity playing a central role.

What biological functionalities lead to creativity's arising? Rössler and Seaman define a set of pragmatic approaches to biomemetics through the abstraction of brain processes, bodily awareness, sensing systems, language acquisition potentials and environmental interaction, in the service of defining our model.

Neuroesthetics is a relatively recent subdiscipline of empirical aesthetics. Empirical aesthetics take a scientific approach to the study of aesthetic perceptions of art and music. Neuroesthetics uses the techniques of neuroscience in order to explain and understand aesthetic experiences at the neurological level. The field was pioneered and named by Semir Zeki, who runs the Institute of Neuroesthetics at University College London. One approach to neuroesthetics is discussed by Zeki. He enfolds the knowledge of the artist as a central part of the discourse:

> Art of course, belongs in the subjective world. Yet subjective differences in the creation and appreciation of art must be superimposed on a common neural organization that allows us to communicate about art and through art without the use of the spoken or written word…It is for this reason that the artist is in a sense, a neuroscientist, exploring the potentials and capacities of the brain, though with different tools.[57]

We are seeking to author a system that engenders a synthetic sense of aesthetics and creativity that "comes to life" in the Neosentient as part of an active learning system with specific operative loops.[58]

In terms of creativity, the pragmatic parameters (discussed above) that articulate Neosentience (as opposed to using a Turing Test for Intelligence) enabled a series of new approaches to multiple fields to be discussed as an off-shoot of this broad inquiry. In my class at Duke University – *The Human as Electrochemical Computer*, a transdisciplinary class exploring notions surrounding Neosentience research was undertaken. Students each developed their own approach to Neosentience research --- not fulfilling all of the above working definitions but creatively applying "some" of the pragmatic definitions of Neosentience to contexts relevant to their ongoing research, e.g. they explored such topic areas as Neosentient Games, Neosentient Interface Design, Noesentient Architecture, Neosentient Information Science, etc. This course presented differing disciplinary perspectives working toward articulating new understandings of the body. These observations were in turn used to elucidate each individual's approach to this new computational and aesthetic paradigm. Discussions/lectures were drawn from the Arts, Humanities, Biology, Cognitive Science, Psychology, Robotics, Physics, Ethics, Artificial Intelligence, Game Studies, and other research areas. The course presented and critiqued current models of the brain/mind/body/environment from multiple scientific (and artistic e.g. the interface) perspectives. Concurrently students developed aesthetic, design-related, scientific and/or conceptual art approaches to the content both alone and/or in groups. The class included invited lectures related to disciplinary / interdisciplinary / transdisciplinary topic areas, and at times the generation of highly focused working groups. These groups sought to articulate bridging languages to enable researchers to talk across disciplinary domains concerning particular research problems that were developed as part of the on-going research. In particular, approaches to the development of a biologically inspired electrochemical computer were discussed and explored.

The notion of generating a multi-modal database was discussed to share knowledge across disciplines, and to potentially become midwife to the production of new knowledge. This later became *the Insight Engine* project. Seaman had distributed his paper: *(Re)Thinking – The Body, Generative Tools and Computational Articulation* outlining the long-term potentials of the Insight engine.

The overarching Neosentient approach to computational creativity draws from studying the body as a holistic ultra-complex system. The Insight Engine is a pragmatic step in this direction. Here, a multi-perspective approach must be taken, encompassing many different fields including studies across the brain sciences; of physiognomy at different scales; experimental interface design; biological functionality; biophysics; electrical and mechanical engineering; mathematics; psychology; linguistics; semiotics; ethics; philosophy; critical theory; studies of perception; the senses; learning; creativity, enculturation and social interaction, etc. Research in each of these differing areas sheds different light on the understanding of the body and its

abstraction as a machinic computational system, helping us to define this illusive holistic picture. My *Insight Engine* project seeks to empower research from different domains to be accessed as part of an interactive, generative, learning system, in the service of just such an undertaking. This system is a computationally "operative" example of what I call *Recombinant Informatics*. The Insight Engine forms a repository for new forms of imaging, textual production and data collection and was discussed in terms of its potential as a research tool via meta-tags, intelligent search mechanisms and relational combinatorics. Thus, the insight engine seeks to be a "pragmatic" computational approach to recombinant informatics, taking its cues from the analogue form of the Neosentience book (discussed above) and the "bisociational" thought model of Arthur Koestler presented in his book – The Act of Creation.[59] Koestler observed creative production in terms of humor, scientific discovery and art.[60] In this book Koestler suggests:

> We learn by assimilating experiences and grouping them into ordered schemata, into stable patterns of unity in variety. They enable us to come to understand events and situations by applying the rules of the game appropriate to them. The matrices which pattern our perceptions, thoughts, and activities are condensations of learning into habit. The process starts in infancy and continues to senility… (Koestler, The Act of Creation p. 44)

In particular he provided the concept of bisociation:

> I have coined the term 'bisociation' in order to make a distinction between the routine skills of thinking on a single 'plane', as it were, and the creative act, which, as I shall try to show, always operates on more than one plane. The former may be called singled-minded, the latter a double-minded, transitory state of unstable equilibrium where the balance of both emotion and thought is disturbed. [61]

The Insight Engine's first formal year of research was funded by the Duke Institute for Brain Sciences as an Art/Science project. The Insight Engine seeks to draw on my long history as a media researcher designing new forms of interface and qualities of interactivity, and to expand this via a strong interdisciplinary collaboration that bridges Neuroscience, Computer Science, the Arts and Humanities, both at Duke and through international collaboration. This research seeks to work toward the digital authorship of a tool to empower insight production, distributed interdisciplinary team-based research and to potentially enable bisociational processes as discussed above.

If we reverse engineer differing research practices across multiple disciplines we can assume that many researchers undertake similar practices— reading papers, viewing diagrams, exploring data sets, creating and viewing visualizations, annotating research materials, watching videos, and partaking in discussions among other activities. Interdisciplinary research also means crossing "linguistic" domains framing that research. Here the generation of shared language (developing bridging languages) is essential. The focus of the research is to heighten the potential for insight production through creative juxtaposition of essential ideas, images and processes— to explore Neuroscience through the associative "lens" of focused computational interactivity, functioning in the service of providing new insights and associations across interdisciplinary research fields, as well as through exploring different concepts and foci from within

individual research domains. One can envision an interactive touch display that enables a user-centric involvement "driving" the generation of a visual set of associative experiences —calling up different PDFs, URLs, images, videos, and computer models as a network of potential associations that are brought into conceptual proximity. Such a work functions both on a local level in a visual installation to be displayed at Duke, as well as on a laptop or ipad driven across the internet.

Outwardly, the initial experience is aesthetic and participatory in nature— the system is designed to be focused in different user-driven directions. Thus, though a network of "pre-seeded" choices one can drive the system to focus on Neuroscience-only related topics of association. Alternately one can juxtapose texts and images from the arts and humanities — poetic texts, critical/social texts, texts related to ethics, or historical texts from multiple fields— this depends on the initial seeding of the system, and choices of the interactant. One can also explore the list of differing research areas from a scrolling list of topics. Thus, one begins with a "seeded" database of relevant "curated" materials. Along with the database which is added to in an ongoing manner, in the future we seek to author the ability to undertake relevant internet searches to bring up new materials for juxtaposition.

In terms of models of creativity, there is one text by Richard Taybor Green, who has a background in developing expert systems for experts. He points to the deep complexity of the subject in his paper entitled *A Model of 42 Models of Creativity*:[62]

> Studying creative people after years of such expert system building, benefited from exposure to heuristics used by a great number of experts in very different fields of work.[63]

Thus how can we glean the patterns that inform creative production. Seaman and Rössler in the Neosentience book present this list of pattern-oriented approaches that might inform future research processes…

> **The nature of meaning arises out of an extremely illusive *plateau space* born of an abbreviated infinity of perceptual pattern-plays (imagination), a history of embodied sensual perceptual instances (sensual in-take), modes of articulation of patterns (language and technological production of patterns), the re-distribution or abstraction of patterns and internal self-reflection related to pattern orientation and also navigation of patterns, and within patterns.**
>
> **Pattern of Patterns / Meta patterns**
>
> **Pattern sensing**
> **Pattern orientation**
> **Pattern comparison**
> **Pattern abstraction**
> **Pattern imagination**
> **Pattern recombinance**

Pattern generation (fragment collages)
Pattern gestalts
Pattern projection (intermingle with environment)
Pattern confluence
Pattern transference (technological production)
Pattern implementations
Pattern re-orientation (categorization)
Pattern strings
Pattern semiosis
Pattern action (spatial/conceptual/relational)
Pattern navigation
Pattern recognition
Pattern truncation
Pattern abbreviation
Pattern mistreatment
Pattern inversion
Pattern realignment
Pattern surgery
Pattern topologies

Pattern topologies Is a new branch of mathematics of which only so far Poincaré's topology exists[64]

So as we move from creativity as a general subject to a more focused approach to creativity as it is applied to the artistic computational realm, this includes many branches of art production, one finds a set of overarching approaches, although this list does not pretend to be exhaustive. Thus, in summary there are a myriad of different ways computers can be drawn upon to augment and/or in the long term become bio-mimetic of human creativity. This includes:

1) The "tool mode" in the creation of a work – like employing photoshop, 3D programs, CAD systems, graphic design programs, 3D printers, computer controlled laser cutters, audio programs (like Ableton Live) etc.

2) The Generative mode – where the creative outcome is potentially emergent in nature. Here a set of algorithms are set in motion and left to their own devices – exemplified by certain a-life works (Jon McCormack talks about biologically inspired computational processes in Computers and Creativity where an interactant intervenes in this process) or self-generative recombinant poetic works, drawing from Combinatorics and a Generative Database Aesthetic as in many of Seaman's contemporary works. Harold Cohen with his painting and drawing machines has also been active via his own particular approach to generative media in terms of painting systems from early on. [65]

3) The interactive mode where the interactant steers this emergent creative production (Seaman called this inter-authorship in his book *Recombinant Poetics*) exploring the

"parameterization" (John Supko's term) of qualities inherent to the system, giving the user access to individual choice, working in concert with the computational system. Although systems can be written that explore "parameterization" as a fully generative process also.

4) The media ecology mode – where interaction is less focused and emerges out of a series of differing "sensed" factors or the behavior of multiple interactants, and/or ecological variables, leading to an emergent outcome.

5) The non-human biological interactant, or computational biological outcome, in part or whole. (As in the work of Eduardo Kac)

6) A more recent goal is to have the system learn and participate (or be programmed with certain "model" selections in mind), in articulating a set of potential aesthetic choices. An example of this might be to have the system listen for particular pitches and then respond in a particular manner. Seaman's early paper on Re-embodied intelligence pointed at modeling a particular aesthetic sensibility and then letting the system generate works based on the computational abstraction of this model in the service of generating a focused "probabilistic" aesthetic outcome.

7) The facilitation of related biological processes that are "steered" by the computer through interaction in some manner. A work like The Telegarden, 1995-2004 by Ken Goldberg et. al.[66]

8) A future approach is the Neosentient Aesthetic approach, where a computer/robotic system learns and then defines it's own sense of creative aesthetic processes, perhaps in part drawing on any of the above approaches. In this sense the computer does not augment creativity but becomes creative in its own right.

9) The sequencing or connecting of multiple machinic events (lighting, sound, prop manipulation etc.) as in a dance or theatre production.

10) The driving or controlling or setting in motion of particular events – architectural scale lighting or signage.

11) Controlling or setting in motion certain biological processes.

12) Creating simulations and/or visualizations of data.

13) Articulating wearable applications to facilitate technical artifacts and/or social interaction.

14) Controlling robotic elements, drones and/or flying pixels.

15) Producing qualities of abstraction either sonically or visually.

16) Empowering architectural activity and reactivity via robotics.

17) Sensing and/or Measuring environmental factors and/or facilitating machinic responses across differing environmental systems.

18) A mixed approach potentially enables a system of systems to function in multiple of the above ways, given different triggering mechanisms and/or or qualities of programming and interaction.

Thus, we have heard some initial ideas related to a multi-perpective approach to Computational Creativity. This is just the computational shadow of a beginning.

Professor Dr. Bill Seaman

November 1, 2013

Appendix

The Many Senses Engine
Bill Seaman with Todd Berreth
http://athanasius.trinity.duke.edu/projects/ems/ems.html

generative installation | sample video/audio output from real-time engine (32:9 aspect ratio for two screens) custom software written in C++/OpenGL, digital video/audio source material.

An Engine of Many Senses is a generative computational work exploring the history and potential future of the computer. It includes a series of media elements that combine and recombine over time -- 3d images, 2d

stills, generative audio, generative media "landscapes", generative text and video components. The work has a series of internal rules that play out different combinatoric strategies, as drawn from an extensive database of architectural typologies and processes. In particular the work includes a series of allegorical time-based images of computers as well as collaged images from the history of the computer and computational history in general. It also includes diagrams of systems that have never been built. The text in the work is combinatoric and is displayed across a series of moving glyphs. The work is always different in that it never plays out the same media elements and/or processes. It is an example of computational creativity. The work is emergent in nature. It can be show on a series of high-definition screens, or via projections in architectural settings.

The allegorical computers include: 1) world - World Computer – Digital Philosophy for Fredkin/Wolfram 2) binary - Von Neumann Machine – for Turing and von Neumann 3) differential - Abstracted Differential Analyzer – for Vannevar Bush 4) dna - DNA Computer for Michael Conrad and Leonard Adleman 5) neural - Neural Network for Hava Siegelmann and Steven Smale 6) human - Human as Computer for Seaman and Ada Lovelace 7) light - Light Computer (Rössler/Seaman) 8) memex - Memex for Vannevar Bush 9) nano - Nano Computer for Eric Drexler 10) electrochemical - Electrochemical Computer for Gordon Pask 11) quantum - Quantum Computer for David Deutch and Stuart Hemeroff 12) replicant - Self-replicating Computer – for von Neumann 13) spin - Electron (Spin) computer for Rössler/Seaman 14) time - Time Computer (T-Computer) for Scott M.Hithcock 15) analogue - Analogue Computer / Maverick Machine for Gordon Pask 16) wave - Wave Computer/ Well Stirred – for O. E. Rössler and Hugh Everett the 3rd

The Engine of Engines
http://www.youtube.com/watch?v=c6iENftQThc&feature=youtu.be

Daniel Howe and Bill Seaman generative video/audio/text installation (2011 - present) was written in adobe air. The 'Engine of Engines' is a generative sound & video installation that responds in real-time to network traffic in the local environment. In the Hong Kong debut (see video), sixteen self-contained nodes, each comprised of a screen, processing-unit, audio output, and flash memory, are suspended in space by connective wire. Together these nodes react dynamically to the nearly one thousand computers in the School of Creative Media's labs, offices, and classrooms.

A China of Many Senses
http://athanasius.trinity.duke.edu/projects/acoms/acoms.html

Bill Seaman with Todd Berreth's generative installation / architectural projection documented at Nasher Museum of Art, Durham, NC, featured exhibition at CHAT 2012 Festival. The artwork is driven by a software engine written in C++ and OpenGL. In real-time, it functions in a recombinant manner to explore a library of disparate elements, video and image content, 3d models and musical passages, functioning as an evocative dynamic collage, media landscape and hyper-constructed assemblage. A China of Many Senses specifically juxtaposes imagery from China's past and present, highlighting the tension of a country rapidly

becoming the world's industrial powerhouse, while simultaneously maintaining many of its ancient modes of existence. It frames, orders and builds with these materials, using a vocabulary and grammar of designed behaviors and construction typologies, diagramming and displaying the permutations with standard modes of architectural representation.

Light Folds – The Seaman and the Tattered Sail
Craig Tattersall and Bill Seaman
http://light-folds.tumblr.com

Light Folds, an experimental music project that includes over 9 hours of audio by *The Seaman and The Tattered Sail* is a collaboration between Craig Tattersall (The Boats, The Remote Viewer, The Humble Bee, Cotton goods, Theodore and Hamblin, The Famous Boyfriend, etc.etc. and artist/designer) and Bill Seaman (SEA, Attsea, Otic.Info.Set, Sp.op.cit, Spilly and the Drops, etc. and media artist exploring linear and interactive works). The work was constructed via the internet, sending differing files back and forth using Drop Box, wetransfer.com, and vast quantities of email.

Tattersall brought his distinct form of “dusting” which explored unique forms of noise, tape ambience, tape degradation, etc. Seaman often explored abstraction using Ableton Live, especially in terms of time / pitch manipulation, and exploring the combination of a multitude of Ableton plug-ins.

S_Traits
John Supko and Bill Seaman
http://www.johnsupko.com/S_TRAITS-with-Bill-Seaman

Seaman and Supko are working on a generative audio engine using Max MSP. The work explores a number of generative sonic processes: the system will seek to function in an “intelligent” manner, in part listening to its choices and responding by making further choices. It will explore the following generative processes: juxtapose different files, repeat a single file, repeat two or more files, reverse one or more files, add a long file (counterpoint), add silence (sound file silence), slow down a file, speed up a file, combine two files (tracks), crossfade two files, transpose a file, slow fade in of files, slow fade out of files, repeat sections, inter weave sections / layer, define a counterpoint of sections, derive pitch info from sections, then create midi files, and make a new “pure” layer from the midi, degrade file or files. The engine will create an ongoing generative mix which will potentially be infinite in duration.

The Insight Engine
Bill Seaman, Todd Berreth, Olivier Perriquet
http://www.dibs.duke.edu/research/profiles/98-william-seaman

This research seeks to work toward the digital authorship of a tool to empower insight production, distributed interdisciplinary team-based research, and to potentially enable bisociational processes as discussed by Arthur Koestler in *The Act of Creation*. The goal of the 1st year of research is to create an interactive system to enable intelligent juxtaposition of relevant media elements via focused interaction, dynamic computational functionality, and intellectual "seeding" of the system. An installation, internet based application, paper/report, and linked conference will also be facilitated as an outcome of the 1st year of research.

The Architecture of Association
Bill Seaman and Daniel Howe
http://projects.visualstudies.duke.edu/billseaman/seamanhowe/aoa/aoa.htm
Adobe air

The Architecture of Association is a large-scale, generative artwork that draws associative links between media elements to form an evolving visual collage. A distributed flow of image, video and poetic text is "intelligently" distributed over a number of display surfaces. As the work is emergent in nature, it does not repeat sequences of images or texts but instead dynamically generates a continuously recombinant network of associations. In 1995, Seaman coined the term 'Recombinant Poetics' to articulate a set of generative virtual worlds.

Neosentience – the Benevolence Engine
Bill Seaman and Otto Rössler
http://www.intellectbooks.co.uk/books/view-Book,id=4742/

Neosentience, a potentially new branch of scientific and poetic inquiry related to Artificial Intelligence, was first suggested in a paper by Bill Seaman as part of a new embodied robotic paradigm, arising out of ongoing theoretical research with Otto E. Rossler. Seaman, artist-researcher and Rossler, theoretical biologist and physicist, have been examining the potential of generating an intelligent, embodied, multimodal sensing and computational robotic system. Although related to artificial intelligence the goal of this system is the creation of an entity exhibiting a new form of sentience. Its unique qualities will be discussed. 'Sentience' is not yet used in the formal languages of either cognitive science or artificial intelligence. Two related approachesare (1) the generation of artificial minds via parallel processing, in a robotic system; (2) an alternative approach is the generation of an electrochemical computer as a robotic system. Biomimetics, along with state-of-the-art computer visualization is employed. The electrochemical paradigm has a complexity that exceeds standard computational means. The scientific and the poetic elements of the project are motivated by human sentience. This transdisciplinary approach necessitates different forms of inquiry to inform this project such as cognitive science including mathematics, psychology, education/learning, neuroscience, linguistics,philosophy, anthropology, biology and the arts.

The notion of building a model for a Neosentient computer and related robotic system is both an exciting and daunting task. In order to model and ultimately build such a device one seeks to borrow important operative concepts and processes from the body and re-understand
them in the context of a mechanism that is not human in nature. We have articulated the following 'Operative Definition' of Neosentience - We consider a neosentient robotic entity to be a system that could exhibit well defined functionalities: It learns; It intelligently navigates; It interacts via natural language; It generates simulations of behavior (it 'thinks' about potential behaviors) before acting in physical space; It is creative in some manner; It comes to have a deep situated knowledge of context through multi-modal sensing; It displays mirror competence. We have entitled this entity The Benevolence Engine. The interfunctionality is complex enough to operationally mimic human sentience. Benevolence can in principle arise in the interaction of two such systems.

See billseaman.com

---

[1] Boden, M. (2010) Creativity and Art, Oxford Press, p. 29
[2] LOVELACE, A. (1842) *Notes By The Translator (of Sketch of the Analytical Engine by L. F. Menabrea*) Biblioteque Universelle de Geneve, October, 1842, No. 82 in Charles Babbage and his calculating engines; selected writings by Charles Babbage and others. Edited with an introd. by Philip Morrison and Emily Morrison. Author: Babbage, Charles, 1791-1871.
Publication Details: New York, Dover Publications [1961]
[3] Wilson, S. (2002) Information Arts: Intersections of Art, Science and Technology , Cambridge, MIT Press
[4] http://userwww.sfsu.edu/infoarts/links/wilson.artlinks2.html
[5] Kay, A. (1989) User Interface: A Personal View. http://proteus.fau.edu/practicum/texts/kay.pdf (accessed 26, October, 2013) p121
[6] Manovich, L. (2013) Software Takes Command, Bloomsbury, New York, p. 98
See also Kay, A. (1989) User Interface: A Personal View. http://proteus.fau.edu/practicum/texts/kay.pdf (accessed 26 October, 2013)
[7] Seaman, Bill 1998, "Emergent Constructions: Re-embodied Intelligence within Recombinant Poetic Networks", Digital Creativity 1998, volume 9. No. 3 pp 153-160"
[8] Seaman, Bill (1999) *Recombinant Poetics — Emergent Meaning as Examined and Explored Within a Specific Generative Virtual Environment.* Available from VDM press, 2010
[9] CASTI, J. 1994. *Complexification: Explaining an Illogical World Through the Science of Surprise.* New York: Harper Collins. "The main claim of Wittgenstein's picture theory is that there must be a link between the logical structure of a given language and the logical structure of a real-world fact that a statement in that language asserts. Since the link is itself a relationship in the real world, it's reasonable to suppose that there is some way to express the character and properties of this link using the grammatical rules of the language. But after years of struggling with exactly how to do this, Wittgenstein came to the conclusion that the link between the real world and its expression in language cannot be "said" at all using language; rather it must be "shown." We can't express everything about language using language itself; somehow we must transcend the boundaries of language. Thus Wittgenstein says that we cannot really speak about the world, but only 'point.' "(Casti, 1994, p.7)
[10] Clancey, W. (1997) Situated Cognition - On human knowledge and computer representations.
Cambridge University Press: 1997
[11] Boden, M. (2010) Creativity and Art, Oxford Press, p. 2
[12] ibid
[13] ibid, p 10
[14] Rosch, Thompson and Francisco J. Varela. 1991. *The Embodied Mind: Cognitive Science and Human Experience.* Cambridge, MA: MIT Press.
[15] Varela,F., Thompson, E., and Roshe, E. (1991) *The Embodied Mind, Cognitive Science and Human Experience.* Cambridge/London: MIT Press.

[16] Seaman, B. (2005), "Pattern flows/hybrid identity construction", Convergence: the International Journal of Research into New Media Technologies, 11: 4, pp. 12–31.
[17] Foerster, H. von (1981). *Observing Systems*. Intersystems Publications
[18] Ashby, R. (1965) Cybernetics, Chapman & Hall London
[19] Pask, G. (1961) An Approach to Cybernetics, Harper + Brothers, New York, p.9
[20] Christopher G Langton (1998). *Artificial life: an overview*. MIT Press. ISBN 0-262-62112-6
[21] Pask, G. (1961) An Approach to Cybernetics, Harper + Brothers, New York, p.9
[22] Fernández, M. (2008) "Gordon Pask: Cybernetic Polymath," Leonardo: Journal of the International Society for the Arts Sciences and Technology, Vol. 41, No, 2 (April 2008).
[23] Reichardt, Jasia [editor] (1968) Cybernetic Serendipity: The Computer and the Arts. Praeger
[24] The Cybernetic Serendipity Archive, http://cyberneticserendipity.net (accessed 17 October, 2013
[25] Fernández, M. (2008) "Gordon Pask: Cybernetic Polymath," Leonardo: Journal of the International Society for the Arts Sciences and Technology, Vol. 41, No, 2 (April 2008).
[26] McCormack, J. and d'Inverno, M.(2011) Computers and Creativity, Springer, NY
[27] Pask, G. (1958) Physical analogues to the growth of a concept. Mechanization of Thought Processes, Symposium 10, National Physical Laboratory, November 24-27, 1958. H.M.S.O. (London) p. 765-794.
[28] Ashby, W.R. Can a mechanical chess-player outplay its designer? British J. for the Philosophy of Science. 3 (1952), 44-57. Reprinted in Mechanisms of Intelligence: Ross Ashby's Writings on Cybernetics , R. Conant (ed.)
[29] McCormack, J. and d'Inverno, M. (2011) Computers and Creativity, Springer, NY
[30] W. Seaman, *The Engine of Engines - Toward A Computational Ecology*, in Integral Biomathics: Tracing the Road to Reality - Proceedings of ACIB'11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath'2011 Workshop at ECAL'11, Paris., edited by Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).. (Winter, 2011) (July 13, 2012), ISBN 3642281109
[31] Seaman, B. (2012) Neosentience and the Abstraction of Abstraction, in proceedings from European Meetings on Cybernetics and Systems Research, Vienna (EMSCR 2012), abstract found online at http://www.emcsr-conference.org/2012/paper/view/140 (accessed 26 October, 2013)
[32] Wiener, N. (1948), Cybernetics: Or Control and Communication in the Animal and the Machine. Paris, (Hermann & Cie) & Camb. Mass. (MIT Press) ISBN 978-0-262-73009-9; 2nd revised ed. 1961.
[33] Ibid page 4 of the revised edition
[34] Licklider, J. (1960) Man-Computer Symbiosis, IRE Transactions on Human Factors in Electronics, volume HFE-1, pages 4-11, March See also http://groups.csail.mit.edu/medg/people/psz/Licklider.html (accessed 15 October, 2013)
[35] Licklider, J. (1960) Man-Computer Symbiosis, IRE Transactions on Human Factors in Electronics, volume HFE-1, pages 4-11, March See also http://groups.csail.mit.edu/medg/people/psz/Licklider.html (accessed 15 October, 2013)
[36] ibid
[37] McCormack, J. and d'Inverno, M. (2011) Computers and Creativity, Springer, NY
[38] Dawkins, R. (1986). The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe Without Design, Penguin, London.
[39] Takagi, H. (2001). Interactive evolutionary computation: Fusion of the capabilities of ec optimization and human evaluation, Proceedings of the IEEE 89: 1275–1296.
[40] Sims, K. (1994). Evolving 3d morphology and behaviour by competition, Artificial Life IV Proceedings, MIT Press.
[41] Bentley, P. J. (1999a). From coffee tables to hospitals: Generic evolutionary design, in P. J. Bentley (ed.), Evolutionary Design by Computers, Morgan Kaufman, San Francisco, CA, USA.
[42] Bentley, P. J. (ed.) (1999b). Evolutionary Design by Computers, Morgan Kaufman, San Francisco, CA, USA.
[43] McCormack, J. and d'Inverno, M.(2011) Computers and Creativity, Springer, NY p. 379
[44] Von Foerster, Heinz, Understanding Understanding
[45] Müller, A. and Müller, K. (2007). An Unfinished Revolution? Heinz von Foerster and the Biological Computer Laboratory | BCL 1958-1976,Edition Echoraum
[46] Von Foerster, Heinz, Understanding Understanding
[47] http://arxiv.org/pdf/1210.7784.pdf (Accessed 27, October, 2013)
[48] Markoff, J. Computer Wins on 'Jeopardy!': Trivial, It's Not,http://www.nytimes.com/2011/02/17/science/17jeopardy-watson.html?pagewanted=all&_r=0 (accessed 17 October, 2013)
[49] W. Seaman, *The Engine of Engines - Toward A Computational Ecology*, in Integral Biomathics: Tracing the Road to Reality - Proceedings of ACIB'11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath'2011 Workshop at ECAL'11, Paris., edited by Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).. (Winter, 2011) (July 13, 2012), ISBN 3642281109
[50] Diebner, H., Druckery, T. and Weibel, P. (2001), "Science of the interface", Proceedings of the International Symposium, ZKM, Karlesruhe.
[51] Diebner, H., Druckery, T. and Weibel, P. (2000) see http://hayles06.wordpress.com/2009/10/13/135/ (accessed 17 October, 2013); see also Diebner, H., Druckery, T. and Weibel, P. (2001), "Science of the interface", Proceedings of the International Symposium, ZKM, Karlesruhe. http://on1.zkm.de/zkm/stories/storyReader$1749 (accessed 17 October, 2013);
[52] Kurzweil, R. (2005), The Singularity is Near, New York: Viking.
[53] Seaman, B. and Rössler, O. E. (2011). *Neosentience | The Benevolence Engine*. London: Intellect Press
[54] Bill Seaman, Neosentient Design, Presented in Your Brain on Art, Neuroaesthetics Symposium, Duke University. May 7, 2008. http://eventful.com/durham/events/symposium-your-brain-art-probing-neuroaesthetics-/E0-001-010061552-5
[55] Jagielski, R., An application of neural networks to emulation of aesthetic judgements,

http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=323009&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel2%2F924%2F7708%2F00323009 (accessed 25 October, 2013)

[56] See for example, The International Network for Neuroaesthetics, http://neuroaesthetics.net/2011/08/21/toward-a-brain-based-theory-of-beauty-ishizu-zeki-2011/ (accessed 25, October, 2013)

[57] Semir Zeki, Statement on Neuroaesthetics, http://www.neuroesthetics.org/ (accessed 25 October, 2013)

[58] Seaman, B. and Rössler, O. E. (2011). *Neosentience* | *The Benevolence Engine*. London: Intellect Press

[59] Koestler, A. (1964) The Act of Creation, NY: Macmillan Co.

[60] Koestler, Arhtur, *The Act of Creation*, NY: 1964 Macmillan Co.

[61] ibid

[62] Tabor-Green, R. A Model of 42 Models of Creativity, http://www.scribd.com/doc/2149673/A-Model-of-42-Models-of-Creativity-by-Richard-Tabor-Greene-20june06-PDF-for-Global-Distribution-FINAL (Accessed September 20, 2013)

[63] ibid

[64] Seaman, B. and Rössler, O. E. (2011). *Neosentience* | *The Benevolence Engine*. London: Intellect Press

[65] See http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w05/cohen_h.htm (accessed 26 October, 2013)

[66] Goldberg, Ken, *The Telegarden*, http://goldberg.berkeley.edu/art/ (accessed September 20, 2013)
The TeleGarden is an art installation that allows web users to view and interact with a remote garden filled with living plants. Members can plant, water, and monitor the progress of seedlings via the tender movements of an industrial robot arm.