From Neosentience to Recombinant Informatics – A Research Overview

Professor Bill Seaman PhD
Member of Duke Institute for Brain Sciences
Visual and Media Studies, Department of Art, Art History & Visual Studies
Duke University

Abstract

An overview of Seaman's research relevant to new forms of *Computer Science, Technology and Application* covers a number of different theoretical research areas and approaches including the examination of new (and historical) studies that seek to look holistically at particular relations at operation in the mind/brain/body/environment, functioning across different scales, and applying aspects of their study to new computational forms. Seaman is interested in what he calls a multi-perspective approach to knowledge production. He is deeply interested in the trajectory of research started in Cybernetics at the Biological Research Lab headed by Heinz von Foerster [1][2][3][4][5][6], yet points to work by Rashevsky [7] as an important precursor, along with McCulloch and Pitts[8]. Cyberneticist Gordon Pask is of particular interest because he also explored a range of pursuits form the sciences[9][10][11][12] to the arts [13] to architecture [14] and learning systems/conversation theory, and 'teaching machines'[15]. Pask, like von Foerster was also interested in new forms of computation and dynamic interactivity. We can trace a lineage from studies in Cybernetics to the study of contemporary complex systems. From this broad research agenda Seaman seeks to work toward the creation of new computational systems and in particular, new approaches to transdisciplinary research that point at forms of computation in the body, and explore these through biomimetics and bio-abstraction. As a media researcher, Seaman seeks to bring his knowledge of computational media, and broad historical research drawn from multiple disciplinary fields, into dynamic relationality. Central to this broad set of studies has been the articulation with scientist Otto Rössler, of a series of disparate research areas that might be enfolded in the creation of a new form of robotic leaning system, that again draws from biomimetics and bio-abstraction, discussed in their book – *Neosentience | The Benevolence Engine*.[16] This book provides a series of micro-chapters that let researchers explore a set of disparate foci in a non-linear manner. Seaman describes this approach as "Recombinant Informatics"[17] — the juxtaposition, combination and recombination of differing informational contexts in the service of insight production. Seaman's broad theoretical research agenda focuses in part on entailment structures [18] and the deep study of multiple physical processes as they contribute to "computation" in the body[19]; the long-term expansion of computational forms, exploring the notion of creating an electrochemical computer inspired by biomimetics and bio-abstraction[20][21]; the development of a network of computers inspired by computation in the body— *The Engine of Engines*; the bringing to light of relevant biologically related historical research that to some degree has been left out of the central discourses in multiple scientific disciplines and in computer science— in particular work done at the Biological Computer Lab headed by Heintz von Foerster [22]. In order to deal with the complexity of these issues in a pragmatic manner Seaman along with Todd Berreth and Olivier Perriquet are working on the creation of a new computational system to help facilitate this research and other disciplinary, interdisciplinary, and transdisciplinary research relevant to *Computer Science, Technology and Application*, entitled the *Insight Engine*.[23] [24]

Keywords
Biomimetics • Bio-abstraction • Biocomputation • Learning Systems • Robotics • Electrochemical Computer • Neosentience • Recombinant Informatics

From Neosentience to Recombinant Informatics – A Research Overview

Media Researcher:

Seaman has focused his media research in the last decade on new forms of computation, learning systems, computational creativity, interfaceology and human/machine interactivity. The term Interfaceology was coined by Otto Rössler and points to the breadth of interface studies, which look as much at physical, biological, mathematical, and engineering aspects of the interface as it does the historical, philosophical, social, and artistic.[25] Seaman is deeply interested in what he calls a multi-perspective approach to knowledge production which is transdisciplinary in nature. His papers have primarily been published in journals and books open to transdisciplinary research as well as in books that have included interdisciplinary and/or team-based transdisciplinary research agendas. His primary media research during this period has been in exploring theoretical approaches to robotics, and learning systems, drawing inspiration from the body's deep bio-functionality, and applying this knowledge through bio-mimetics and bio-abstraction. This research has also included a close look at the histories of multiple related fields. In order to define such complex systems one must first come to better know the body from multiple disciplinary perspectives, as well as discuss how these perspectives can be applied in new and on-going forms of research— thus the transdisciplinary team-based approach is necessitated, where differing researches bring deep knowledge to problem solving, as well as developing new methodologies, language and approaches to computational systems, to enable them to collaborate in exploratory areas that have not historically been fully articulated. New concepts and research agendas often arise in the space between disciplines, through the development of what Seaman calls 'bridging languages'. Central is an onging set of discussions that unpack ideas and concepts which cut across disciplinary domains.

Neosentience Research (Seaman and Rössler)

Seaman and Otto E. Rössler have been involved in a decade long 'conversation' exploring the future of intelligent learning systems, often discussing the historical precursors that have eventuated into the current state of the art. Their long-term goal has been to work toward creating a model for an autonomous, intelligent, embodied, multimodal sensing and computational robotic system. Rössler best know for the Rössler attractor [chaos theory] and his ideas surrounding Endophsics – a model physics, and Seaman, media researcher, wrote a book entitled *Neosentience / The Benevolence Engine*[26] to capture the breadth of this ongoing exchange. The book is a highly transdisciplinary non-linear manuscript drawing from many research fields. It includes quotes from scientists, philosophers, historians and additionally points to particular works of art, the history of science, and science fiction as precursors to this undertaking. This transdisciplinary approach necessitated drawing on different forms of inquiry to inform the project including texts from cognitive science— psychology, education/learning, biophysics, neuroscience, linguistics, philosophy, anthropology, biology as well as the arts and humanities. Seaman coined the term Neosentience arising out of this ongoing "conversation" with Rössler to help elucidate this new embodied robotic paradigm. For each micro-chapter Seaman and Rössler provide a comment or central concept. They also draw from their historical papers to help elucidate the subject. [27][28][29][30][31][32][33][34][35][36][37][38][39][40][41][42][43][44][45][46][47][48][49][50][51][52][53][54][55] It is clear that Rössler brought to the research an interesting breadth of thought, through his earlier research and study of Ethology with Konrad Lorenz, and his theoretical research across multiple fields.

Neosentience (Seaman and Rössler)

Although related to artificial intelligence the goal of this system is the eventual creation of an entity exhibiting a new form of sentience. Its unique qualities were discussed at length in the book.

'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. 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. The notion of building a model for 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.

A Pragmatic Approach(Seaman and Rössler)

Seaman and Rössler consider a Neosentient robotic entity to be an autonomous learning system that could exhibit well-defined functionalities that draw from our study of human bio-functionality: 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 multimodal sensing; it exhibits a sense of play; it will be mirror competent and will in this sense show self-awareness; It will be competent to go through the personogenetic bifurcation (thereby acquiring the ability to articulate meta-levels and meta-patterns). We have entitled this robotic 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.

Each of these "pragmatic" benchmarks (as distinct from the Turing Test) [56] were discussed in relation to earlier cybernetic research, as well as other relevant research histories related to the study of intelligent machines. The Neosentient will be brought up (brought to life) in a social and cultural sphere of reciprocal inter and intra-actions contributing to language and knowledge acquisition. This is achieved thought embodied relations to the environment, self and others.

The Neosentience book took on a unique non-linear form, providing literally hundreds of microchapters for the reader to navigate and explore. It is an excellent sourcebook for transdsiciplinary research in that most chapters also point to one or more importance reference works. In a note from the authors Seaman and Rössler provide this frame:

> We write this book as a circulating heterarchy. It can be read in differing or chance orders. This document arose out of many years of conversation between the authors. Our goal for the book is to spark new thoughts via the differing juxtapositions and the compressed ideas that it presents. This text is a piece of recombinant informatics. Take any two micro-chapters and build a conceptual bridge between them. We think that the fragment worlds presented here are compatible. Collisions of contemporaneous and historical ideas function as a springboard for radically new ideas. Let this book be an inspiration to future research. Its micro-chapters can be endlessly recombined as a hopeful pass toward Koestler-type bisociation[57]. Science moves forward by articulating doubt. Everything we take for granted has a limit that may one day be transcended.[58]

Seaman had in 2005 written a paper, entitled *Endophysics and The Thoughtbody Environment – An outline For a Neo-computational Paradigm* which was published on the internet. This paper was also inspired by conversations with Rössler. In it Seaman discusses the The N_S.E.N.T.I.E.N.T. Paradigm, which was elaborated in the Neosentience book:

> This is a new paradigm that is intended to lead toward a new notion of personhood. Is it Non-sentient or Neo-sentient, that is the question. We can not know if there is consciousness in any machine, including our neighbor's brain.
> • Neosentient – the system is to exhibit sentience of a new variety;
> • Self-organizing – the system is self-organizing;
> • Environmentally embedded – the robotic system should be situated and context-aware and be directly or remotely connected to a multimodal sensing system;
> • Nascent – the system is "brought to life" and learns over time, building up a body of placeoriented knowledge; it is not alive in the sense of a living metabolizing organism, but it is "alive" in the sense of a conscious functioning in the world;
> • Temporal – the system functions in relation to multimodal time-based flows of differing

machine-oriented “sensing” inputs, the parsing of the latter through pattern recognition and operations on those patterns (internal abstraction);
• Intra-active – the entity arises through a reciprocal interaction with other individuals. Because direct input might be facilitated between “entities” in new forms of human/entity communication, we use the prefix (intra) suggesting a different order of connectivity in communication. The system develops an ongoing “projective” abstraction;
• Emergent – the entity’s actions arise in context and are not known in advance but “come to life” in relation to environmental conditions, a series of “emotional” force field-based attractions and repulsions, and historical interactions and intra-actions;
• Navigational – it can move about to function in an appropriate manner and become context aware across multiple domains;
• Transdisciplinary – the research is influenced by multiple disciplines as it emergently unfolds. As the entity learns and becomes self-aware, Neosentience will also be something it learns about, and it may become a participant in its own discourse. We seek to have Neosentience arise as an emergent property of the system.
Our system functions as a self-consistent set of loops without the need of added qualia. It appears that the force fields function as surrogate feelings/drives and thus function as a perfect substrate for qualia. [59]

Introduction – Bridging (Seaman and Rössler)

The book speaks of two different approaches, the top down approach of Rössler’s Brain Equation, and the bottom up approach drawing from biomimetics and bio-abstraction. Of course the answer will arise at some point through a long-term conversation between the two. Central to the concept of Neosentience was Rössler’s concept of the Brain Equation.

Introduction to the Brain Equation (Otto Rössler)

The Brain Equation exists because survival in space is a different problem than survival in time. Darwin solved the problem of continued survival of a species in time. It is only through the random endogenous changes that arise (“mutations” they were called later) that a species can keep being adapted in an unpredictably changing environment as is unavoidably the case in the long run. Yet if survival depends on position in space, there also is only one way to be successful: move. That is, to either go to a better place or a less dangerous one. This is a wellposed mathematical problem. If survival depends on position, the only way to improve survival is to build a “brain.” This brain implements a certain solution to a well-posed mathematical problem: the traveling-salesman-with-alarm-clocks problem. This brain is different from the “brain in the genome,” as Michael Conrad called it. Evolution always proceeds by carrying its own past on its back – by literally carrying its genetic machinery on its back. Each successive generation reaps the fruits of the most recent mutations as well as all earlier mutations (as a sum of histories as it were). But the brain equation is independent of history. Like the liver, the brain is an organ based on the Darwinian genomic path. The intuition of the brain equation arose because Konrad Lorenz drew attention in a personal discussion to the difference between genetically controlled adaptive responses and environment-controlled specific temporal ones like a tidal cue. These not genetically predictable events are equally important for survival. To this “second class” belong all spatial relations.[60] [see a Synopsis of The Brain Equation from Rössler in the appendix]

The Brain equation is an equation of the force field of all desires. It is based in spatial Darwinism as a part of deductive biology.[62] It is hard to sum up the final section of the book where we provide our model for the Neosentient, so I will here present a long quote that discusses the components of the model we present in the book. Here is our operational diagram.

Diagram here (see jpg attached)

Poly-sensing Input - Machine multimodal sensing (Seaman and Rössler)

The Benevolence Engine begins with a series of input devices – a machine-based multi-modal sensing system— a Polysensing system (Seaman’s coin).[63][64] One can imagine one’s own senses being abstracted in service of such a mechanism, although machine-based sensing potentials will be quite different in sensitivity to their human counterparts, that is, one can imagine a system being implemented with infrared vision etc. Embodied multimodal sensing has been discussed by Agre and Suchman.[65] Such multimodal approaches were initially discussed early on (in the 1990s) by people like Brooks.[66] This represents a quite different perspective to earlier A.I. projects that were not “embodied” and did not see the importance of coming to a deep knowledge of context via multimodal sensing systems that would be dynamically linked to their

environment. The concept of “Pattern Flows”[67] is discussed in Seaman’s paper “Pattern flows | hybrid accretive processes informing identity construction”. This paper points to the potentials of “pattern flows” of sense inputs as a means of coming to understand meaning production. L. Barsalou has conducted much research in this area.[68] So has Charles Spence at the Cross-modal research lab, providing research into the nature of multimodal sensing.[69] Peter Cariani has also written about sensing and Temporal Codes.[70] Jon Bird and Andy Webster also explored related electrochemical sensing topics.[71] Multimodal sensing systems enable the transduction of sense data into a “pattern language” the system can utilize. This represents a set of processes that contribute to the potential arising of Neosentience. Synthetic senses can have different qualities to that of their human counterpart – there can be more of them and they can exhibit different sensitivities to that of the human. Thus the Benevolence Engine’s “phenomenological” experience would be of itself because the machine-based senses would give it a qualitatively different ongoing understanding to that of the human sensorial domain. Consider our understanding of the stars using human vision. Then consider our understanding of the stars after the invention of the telescope. We might also picture radical connectivity to devices like scanning/tunneling microscopes. If a series of machine-based senses were the normal senses that functioned together to form an understanding of the world for the Benevolence Engine, its general perception of the world would differ from that of the human. One might argue that the same technologies function as extensions of our own senses, such that there would not be a difference. We believe the integrated use of multiple non-human sensing systems will contribute a different understanding of the world and thus help generate this state of Neosentience – a sentience based initially (in part) on the abstraction of human sensing. Our system would contribute to coming to know the world in a unique manner.

Pattern Matching Mechanism (Seaman and Rössler)

The system would observe in a form of foveal 3D,[72] defining an updatable map of the environment (by having the input partially abstracted and simplified on the way), generating a virtual environment that can later be drawn upon for pattern recognition purposes as well as to enable a correlate of “closed-eye vision” for navigation of imagined spaces before acting in physical space. This is an automatic implication of the above “wiring” diagram. If we think of a human acting in physical space we perform within a layered topological space[73] by superimposing our human emotional space (our feelings, attractions, and repulsions to situations and needs) with physical space. Emotional space and physical space are conjoined and can be contemplated before action is undertaken. This forms a topological–psychological space where many factors (other parts of the system) play into the “understanding” and “parsing” of sensed stimulations and environmental differences. We “build up” knowledge and use it in a projective manner, in forming the understanding of incoming data. A goal of the system – meaning acquisition through “patterns flows,” will enable the entity to form new understandings through learning and a creative combinatoric pattern re-application. Each individually sensed aspect of a linked set of multimodal memories can lead back to the memory of the original pattern (or constellation of multimodal inputs) through pattern matching. Any scene could just be retrieved from the combined emotional vector, momentarily applicable to it. The system would automatically generate “Platonic ideation” in the sense of Heinz von Foerster [74] or averaging [75]– enabling potential recombinant collage-like “creations” built of past relations, mixed with updated information and language. Buffer-generated VR— The entity is embodied and embedded in the environment. Multimodal senses provide deep knowledge of the environment that is built up slowly through learning and the interfunctionality of the differing branches of the system’s functioning over time. A virtual picture of the environment is being built up in real time. The memory of this picture becomes abstracted by the system. High-resolution storage of all situations over time is not “economically” viable for the system with a finite memory space. The system “experiences” in high detail, with foveal focus shifting across individual senses and multi-modal relational centers. The entity builds up averaged patterns through simplification/abbreviation/metonymy (platonic reference) through the averaging of patterns. The virtual world also stores comparative relations to other correlated time-based sense data. Memory becomes a relational configuration over time [76] and depends on the environment, filling in many

details for actual embodied experience. [77] Multimodal sensing contributes to this relational time-based configuration. The density of detail of this relational set is also decreasing in resolution over time (related to the image content/virtual mapping that is stored) although aspects of the resolution can be built back up with subsequent emulation/simulation and/ or new encounters with similar but different things, updating based on new data, and additional encounters with the environment. A Neosentient approach suggests that this "mind's eye" can be shared with other entities, networked and or made visible in a public manner. Thus again, The Benevolence Engine's "mind's eye" will be significantly different in nature to that of the human. Humans cannot share their mind's eyes in a direct manner. [78] Yet in seeking to posit such a new vision system, one must come to study the functionality of the human visual system, and its relation to other sensing systems in the body in a manner that transcends contemporary science's need to isolate sensing systems – the visual system in particular. Thus new forms of multimodal research must be undertaken and/or abstracted to help us comprehend the inter-functional nature of senses especially in terms of pattern matching, and memory retrieval.

Force Field Generator (Seaman and Rössler)

We must remember that human emotion and human need (drives) play into many of the spatial decisions we make – our human behavior. Again the topological–psychological space of Lewin is invoked – the brain equation and this scheme match his scheme intuitively. A series of "drives" (internal emotional forces) suggest for us the need to approach and/or avoid differing situations. Our system houses a set of force field sliders that the brain equation controls. These forces would sum in differing ways related to alternate situations. Historical input that is re-associated with the current context through pattern matching, conjoined with current environmental input, is also put into play via the memory element's inner loop. This complex systems approach explains particular behaviors over time. The force field sliders are quantifiable in machine-oriented terms, and controllable/programmable, but they are ordinarily controlled via the environmental input in accord with the brain equation. A Neosentient entity might also be empowered to internally re-set their own force field sliders.

Control Driver: The Great Joystick and the Great Simulator Mechanism
(imagined space) **(Seaman and Rössler)**

This part of the system both steers the behavior of the mechanism (joystick metaphor) and/or performs simulations of what steering the mechanism might accomplish (again related to closed-eye vision) or picturing your behavior before you do it to help make decisions (simulation space). This automatically occurs when the motors and the "visual inputs" are momentarily switched off (closed-eyes optimization mode). In the full-action mode this sends messages to robotic effectors to bring about movement in actual space.

Overlap Buffer (Seaman and Rössler)

The overlap buffer enables the entity to be performing in actual space while simultaneously running simulations (imagined spatial relations) that help the entity make decisions about how to act in that space in the immediate future. The entity thus can focus on the actual view, the imagined view, or a simultaneous mixture. This correlates to the human's ability to close their eyes and just think about a situation, and/or think about it (or other spaces) while simultaneously acting in an environment.

Efference Copy/Reafference (Seaman and Rössler)

This is based on von Holst's Reafference Principle. A control system (the brain), or in this case a computer, has sensory and motor connections to muscle-like effectors. The efference command is the motor command. The reafference is a "sensory" response from the motor. The reafference and the efference copy interact. If these are of equal magnitude and opposite signs, they will cancel each other. If the afference is larger or smaller than the magnitude of the signal in the

efference copy, the signals will not cancel, and the difference between the efference copy and the afference will be transmitted to the control mechanism. [79] Thus, the "exafference" forms a relational connection with the entity's motion and/or behavior within the environment and the entity's pattern matching, control, and simulation mechanisms.

Movement Potentials (Seaman and Rössler)

The system functioning as a unity defines the potential of movement that is directly linked to the environment through the multimodal sensing system, and the knowledge that has been built up concerning the environment over time housed in the memory stores.

Long-term Memory (Seaman and Rössler)

Long-term memory stores particular patterns for long periods of time which are also slowly decaying or losing resolution (in terms of image-based patterns). Thus current pattern matching in the initial buffer enables the entity to do pattern matching with past environmental patterning.

Neosentience (Seaman and Rössler)

Neosentience is a new area of scientific and poetic research. It operates out of a rich series of interrelated research agendas. We have presented the initial plan for a model to address the potential of having neosentience arise through a series of interfunctional processes that have been derived through careful abstraction from evolutionary space-dependent survival scenarios.

Discussion and Summary from the Neosentience Book (Seaman and Rössler)

An artificial mind was proposed. It combines many functional ingredients that apparently have not been employed before, either alone or in combination. The "big screen" is a full fledged virtual reality in the sense of William Gibson.[80] There is an updating involved that automatically generates a natural "nowness." It would not make sense to have an updating rate that is much faster than locomotion and limb movement require. The forces that emanate from source points in the spatial environment are represented on the "big screen." These forces control the locomotion of the artificial organism as prescribed by the implemented force fields of a brain equation. This is done via the [metaphor of the] "big joystick" which is directly "controlled" by the momentary force vectors as determined by environmental input and the time elapsed since certain past encounters and events, dependent on components of the brain equation. The machine would be completely automatic were it not for the added capability of closed-eye locomotion. Here, the clash of some simultaneous forces acting on the joystick immobilizes it momentarily, while giving control over to a simulated mode of locomotion. As soon as the simulation leads to a resolution of the conflict, the lower level joystick takes over again. In this way, the machine is continually on the move, being under absolute control of the time-dependent forces exerted by "sources" in the environment. There is consciousness involved.

If two such machines interact in a cross-caring manner, each can be caught in an attempt to simulate in favor of the other's goals. In this case, the invention of a "hallucinated" other center of optimization occurs. This gives rise to the invention of "benevolence" or more exactly, of the suspicion of benevolence, that is, of getting the impression that another center of optimization exists acting in favor of one's own goals. This presents a much more interesting mode of functioning of the system than simple locomotion. It will be necessary to build two such machines to enable such coupling, to completely understand the emergence of foreign controlled-ness within the system, along with its stopping to function as a subconscious optimizer. Actually the invention of the subconscious by Freud corresponds to the rediscovery of the old lack of consciousness mode in the brain. The real surprise is the emergence of a conscious giving-up of the original subconscious identity through the emergence of a simulated existence that is benevolent toward another simulated consciousness – internally represented by the same system. So, strangely, consciousness is not implied in the machine itself but only in a kind of out-of-

nothing creation within the machine. The ghost of consciousness has no substratum in the hard or software of the system. It is pure fiction made real – it is the only agent to be found.

A second approach has also been discussed, complementing that of the implementation of the brain equation. The second approach explores the biofunctionality of the body at its greatest depth. It seeks to define a set of analogs for biological processes in a biomimetic fashion. This long-term approach (read bottom-up) seeks to re-understand the vast network of entailments of the body that enable it to function. One of the authors was also thinking in this manner when some 36 years ago was writing about "well-stirred" computational processes – laying the foundation for thought surrounding the creation of an electrochemical computer [81]. The creation of a Pandaka pygmaea institute is also an initial step in this bottom-up direction. Alternately, the creation of an "Insight Engine," a technology to help augment approaches to studying and discussing bodily entailment, suggests the need to create technology to help define an even higher order technology – the Neosentient. Although this approach may prove to be problematic due to that which is unknown and unknowable about thought and the body, it may still form a fruitful approach to the generation of a Neosentient entity, which to some degree will be "of itself " given either approach. In fact it may be that both approaches, the top-down approach of the brain equation functioning in "conversation" with a bottom-up bio-mimetic approach, may lead to a functional synthesis.

Simultaneity

Seaman was asked to contribute to a book on Simultaneity. His text was entitled:
Unpacking Simultaneity for Differing Observer Perspectives and Qualities of Environment.

We take for granted that we know what an observer is. In actuality, there are many different kinds of observation that we employ, related to differing qualities of environment. These modes of observation include direct human observation; human observation that is augmented by differing tools and/or machines; computational models functioning as machinic observers, in which humans become super-observers; chemical observers where particular changes register particular qualities; and potential future observers - Neosentient machines. For each of these different kinds of observers, the notion of simultaneity is problematic in some manner. The definition is clear enough: *simultaneous - existing, occurring, or operating at the same time; concurrent: simultaneous movements; simultaneous translation*. Yet, notions of time are different on the micro and macro scale. Humans also have been observed to include up to a one half-second time buffer (See Libet's *Mind Time - The Temporal Factor in Consciousness*), adjusting for the body's distributed sensing functionality and potentially its embodied relation to memory and past thought. These facts throw off our concept of something happening at "the same time." Thus, time, spatial relations, the body, differing machines and chemical modalities each can be framed linguistically as having different perspectives in relation to the notion of simultaneity and/or the limits of registering simultaneous events. [82]

The Insight Engine

Given the complexity of the Neosentience project and attempting to creating a model for an electrochemical computer based on human bio-functionality, Seaman is now in part focusing on what he calls – *Recombinant Informatics* — a computational approach to insight production through dynamic interaction with concepts and research drawn from multiple disciplines. The Insight Engine is centered around the notion of bisociation (mentioned above), originally articulated by Arthur Koestler in his book *The Act of Creation*. "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." [83]

The *Insight Engine* system seeks to reverse engineer some of the processes that we use as researchers. It then works toward a human / machine symbiosis where the machine presents an interface to many different researcher's works. It does so in a way that enables the human user to

playfully explore many different areas of research that may or may not be relevant to their current work in a novel interactive manner. The system presents a "word swirl" to be called into the interface space in 3D for each different researcher. These can be accessed and displayed in the interface or put away. These "word swirls" have buzz words or titles (that individuals and/or Seaman will supply for your own papers) at the top of the hierarchy (one can also look deeper in the hierarchy with multiple finger touches) and even read an entire paper if it is of interest.

Often new knowledge arises in the space between fields —in interstitial zones of knowledge production. If you choose one "buzz word" or paper title from "your" word swirl and one from another researcher that looks to be of interest, the system will seek to find the most relevant examples in the database [by making a comparison of the entire body of the texts nested beneath the surface of the word swirl] (and eventually searching the internet, in the next iteration of the system) and provide associated papers for the user as a new word swirl of the most relevant juxtapositions.

This puts your research in proximity to someone who otherwise might not find it or know of it. Alternately, if you "play" with the system it may provide a juxtaposition that is relevant to you and your research in a new way… in an emergent manner… thus the system might provide a historical instance, or newly published paper, etc. that might potentially suggest a moment of insight for one's research.

The system seeks to be a learning system, where as one explores it, it generates new word swirls of papers or media, that we hope to be relevant, in a playful iterative manner, or one can throw things away that are not relevant. The goal is in generating "intelligent research juxtapositions" that we seek to have arise through the use of the system - either for you or for a person who might learn from your work during their accessing of the system. This presents a situation of mutual intellectual gain between differing researcher. The system and ideas surrounding its creation are talked about at length in Seaman's paper paper *(Re)Thinking — The Body, Generative Tools and Computational Articulation.*[84] I am currently working with programmer/designer Todd Berreth and Olivier Perriquet – programmer, media researcher, scientist and artist on the project.

Integral Biomathics

Seaman took an active role in the team-based research that was published in the book *Integral Biomathics, Tracing the Road to Reality*. "This book is about a new approach to biology (and physics, of course!) Its subtitle suggests a perpetual movement and interplay between two elusive aspects of modern science- reality/matter and potentiality/mind, between physics and biology- both captured and triggered by mathematics- to understand and explain emergence, development and life all the way up to consciousness." [85] It is interesting to read the dedication of the book which speaks to the breadth and depth of ideas historically informing the project: "This book is dedicated to the memories of Alan Turing, Erwin Schrödinger, Nicholas Rashevsky, Gregory Bateson, Michael Conrad, Robert Rosen, Francisco Varela, Valentino Braitenberg and all of the brave research pioneers who dared to question the riddles of life." The Editors. [86] The eventual goal of the research is to define a "set of novel mathematical formalisms capable of addressing the multiple facets of an integral model and a general theory of living systems within an adequate frame of reference."…"INBIOSA's (INtegral BIOmathics Support Action's) task was to identify, consolidate and organize transdisciplinary research in Europe around this focus." Seaman, over the past decade has focused on a broad set of contemporary and historical studies in his work on ideas surrounding the creation of an electrochemical computer, and in his work with O.E Rössler on their book, *Neosentience | the Benevolence Engine*. Simeonov, was aware of aspects this research [87] and brought Seaman onto the transdisciplinary team. The broad goals of the project are as follows: "At its base will be a long-term fundamental research programme in mathematics, biology, and computation on a global scale we call *Integral Biomathics*. The book presents an exciting white paper, many different disciplinary perspectives and concepts, as well as a series of individual contributions elucidating this exciting field."

Seaman worked to help elucidate and structure the broad agenda of the White Paper whose title was "*Stepping beyond the Newtonian Paradigm in Biology towards an integrable Model of Life: Accelerating Discovery in the Biological Foundations of Life*." [88]

The Engine of Engines – Toward a Computational Ecology

Seaman contributed a chapter with the above title to the *Integral Biomathics* book. The paper discussed contemporary research into computation in the body, and the concept of exploring the creation of a diverse network of computers, inspired by this study to expand this research — *The Engine of Engines*.[89] Our knowledge related to the entailments of functionalities of different biological processes as they enable sentience to arise in the human, is still limited due to the biological complexity of the body. There are two interrelated research paradigms that can be developed to approach this problem– one paradigm seeks to study the body and articulate its entailments (intra-functionalities) at multiple scales over time; the second paradigm seeks to glean knowledge from this study of biological processes and create new forms of computation, to enable us to transcend the limitations of current computational modes. The nature and scope of the question necessitates an interdisciplinary (or perhaps transdisciplinary) methodology to research, through the development of a particular multi-perspective approach to knowledge production. Here, key solutions can in part arise at the interstices between disciplines, and potentially enable us to define and 'chip away' at the problem set. Central is observing the body as a distributed network of computational processes that function at different physical scales as well as across time-dependent, process-oriented accretive frames. We can articulate the study of the body by calling it an electrochemical computer— a computer whose deep functionality is not yet fully entailed. Historically the nature of the problem has been to isolate a biological system and study its entailments to ascertain its functionality. Yet, the nature of sentience asks us as researchers to take a more holistic approach, despite the complexity at play. These two paradigms then become a long-term problem set that a network of high-end researchers can collaborate on, by bringing different areas of expertise to the table. The notion of developing a biomimetic/bio-relational *Engine of Engines— A Computational Ecology* [90] derives from observing computational systems at work in the body and approaching them through observation— through technological, mathematical and/or computational abstraction. Where the body has been described as functioning as a computational system that transcends the Turing limit [91][92][93] new approaches to computation need to be undertaken to reflect upon this deep complexity. [94]

The Engine of Engines - Computational processes at operation in the body

Seeing a series of biologically networked computational processes as relevant to human biocomputation, one thus seeks to extend the current model of the Neural Net to enfold other relevant distributed biocomputational and/or bio-relational processes. We can discuss the body as having a number of processes on differing scales contributing to thought and action where mind and body are seen as co-arising via physical processes as discussed early on by von Neumann in his text The General Theory of Automata: *"[…] it is a fundamental requirement of the scientific viewpoint – the so-called principle of the psycho-physical parallelism – that it must be possible so to describe the extra-physical process of the subjective perception as if it were in reality in the physical world – i.e., to assign to its parts equivalent physical processes in the objective environment, in ordinary space."*[95] Yet, at this moment it is still difficult to parse exactly what computational processes in the body are at operation, and in particular how they contribute to neural computation [96]. Here we can take stock of some of the processes that might be considered to contribute to its mixed "computational" nature. These might include: neural flows (mixing analogue and digital processes) including: a) neural transmitters (protein shape communications); b) circulating frequencies – that also function to regulate bodily processes and change synaptic efficacy [97]; synapse flows (changing efficacy in a digital-like manner, in part in relation to a) and b) above); genetic processes contributing to growth and the formation of the systems themselves (DNA); nanoscale processes regulating molecular change and biological communication; flow processes (acting as analogue computation) or vehicles

enabling distributed biological processes; quantum processes in nanotubules and other locations[98]; biophotonic messaging alerting adjacent cells of their death through the release of low level coherent light [98][99] (there is still much debate surrounding this issue); and other biological functionalities still under research (volume transmission) [100]. Additionally the notion of multi-modal sensing and embodied experience becomes an important operational mechanism both in the human and in artificial polysensing environments that might enable a machine to build up knowledge about environment. [101][102] From this list of human/biological computational processes the research field has spawned many biomimetic and bio-relational computational approaches. This includes analogue and digital manifestations e.g. neuromorphic chips [103] Such computers include: protein computers (Biomatic.org Wiki); DNA computers [104]; quantum computers [105][106]; embodied sensing systems informing computation/learning systems – polysensing environments [107]; analogue flow computers [108]; analogue physical computers[1-9], wind tunnel computers, blood flow computers [109]; electrochemical computers [110][111]; nano computers and related nano sensors [112][113]; and neural nets of differing kinds [114].

By networking these many different kinds of computers via the development of new forms of interface, we seek to draw upon the quantitative characteristic differences that make each unique. Many of these computers push "Beyond the Turing Limit." [115] Perhaps each with a special attribute that enables it to perform "particular" kinds of computational processes, or that exploit a particular quality inherent to their physics and/or to their analogical substrates. Yet in almost every case these computers are currently interacted with via von Neumann machines (and/or "human computers" [see the history of computation], that re-encode information gleaned from these machines, translating their output into a form that is compatible with von Neumann machines). The challenge of future research is in the development of new connective interfaces that bridge from the analogue to the digital; new forms of cross functional operating systems that can enable information exchange with the greatest acceptable accuracy; and new forms of communication across scales.

The body achieves a unity bridging multiple scales of computational processes as they become operative in conjunction with other networked biological operations. Certainly Simeonov has charted a new science of mathematical relations separately covering many of these areas of research in his paper entitled: *Integral Biomathics – A Post Newtonian View Into the Logos of Bios (On The New Meaning, Relations and Principles of Life in Science).*[116] One could also work toward emulating these intra-functional systems in von Neumann machines; yet, given the impetus of exploring mixed analogue/digital systems where particular substrates enable new varieties of communication and functionality, it seems important to explore the potentials of mixed analogue/digital computation. Here we encounter two related questions: 1)Biologically, how are such processes in the body currently interfaced so that they become inter/intra-functional at different levels and scales? And, 2) in the development of new modalities of computation can we articulate new forms of interface that enable a transfer of relevant data, without a "significant" loss of the precision and/or specific functional attributes of the individual mechanisms involved, informed by our study of biological entailment?

By linking disperate computers using a von Neumann machine as a "pivoting" hub, and/or by developing specific biomimetic and/or bio-relational forms of functional inter-system interfaces, we can potentially point at and better come to understand complex forms of biological functionality. We can, in some cases divide up problems to be tackled on the computational machines that might best achieve particular focused "mathematical" goals. Not only can we interface with the von Neumann machine, the long-term goal is to facilitate unique interface development between the differing systems. To articulate such an *Engine of Engines* one will need to enable a dramatic "Convergence" between disparate researchers. [117][118]

Summary

Seaman has been involved in a broad range of transdisciplinary research initiatives. As stated above, he is interested in a multi-perspective approach to knowledge production. His media

research surrounding Neosentience with scientist Otto Rössler enfolds multiple subfields of computer science. His *Insight Engine* project presents an exciting new approach for the perusal and dissemination of research data aiming at the dynamic exchange of ideas by facilitating a unique form of collaboration between researchers from different countries via the internet, through a novel computational methodology of interaction. His theoretical approach to the future study of biocomputation in his project the Engine of Engines, explores the creation of a networked ecology of computation, and points at this as a possible means to study biocomputation at work in the body through biomimetics and bio-abstraction. Seaman realizes that many of his projects are large in scope, yet feels that it is important for science to explore highly complex long-term research problems.

References

[1] Foerster, H. von (1967) Theory and Application of Computational Principles In Cognitive Systems, Archives of BCL, University of Illinois

[2] Foerster, H. von (1981). *Observing Systems*. Intersystems Publications

[3] Foerster, H. von (1974). *Cybernetics of Cybernetics* [book] (Originally published by Heinz von Foerster and the Biological Computer Laboratory at the University of Illinois). See also Brun, H. and Sloan, S. (1995). Cybernetics of Cybernetics. Future Systems Inc.

[4] Foerster, H. von (1995). Cybernetics and circularity, anthology of principles propositions theorems…May 17–21, 18–19. Available from: http://www.cybsoc.org/heniz.htm. [Accessed 15 April 2012].

[5] Foerster, H. von and Poerksen, B. (2002) *Understanding systems: conversations on epistemology and ethics*. K. Leube, trans New York, Boston, Dordrecht, London, Moscow: Kluwer Academic/Plenum.

[6] Foerster, H. von (2003). *Understanding Understanding*. New York: Springer

[7] Rashevsky, N. (1933) Outline of a Physico-mathematical Theory of Excitation and Inhibition, *PROTOPLASMA, Volume 20, Number 1*, 42-56

[8] McCulloch, W. and Pitts, W. (1965), "A logical calculus of the ideas immanent in nervous activity", in W. S. McCulloch (ed.) Embodiments of Mind, Cambridge: MIT Press.

[9] Pask, G. (1958). Physical Analogues to the Growth of a Concept, in *Mechanisation of Thought Processes, Proceedings of symposium held in the national physical Laboratory, on 24-27 November, Volume II National Physical Laboratory Symposium #10*. London: Her majesty's Stationery Office, 1959

[10] Pask, G. (1962). *The Simulation of Learning and Decision Making Behavior*. http://www.ntis.gov/search/product.aspx?ABBR=AD638845

[11] Pask, G. and Curran, S. (1982*) Microman: Computers and the Evolution of Consciousness*. New York: Macmillan.

[12] Pask, Gordon, An Approach to Cybernetics With a preface by Warren S. McCullock, (Massachusetts Institute of Technology) HARPER & BROTHERS, New York, 1961, (pg. 105)

[13] Pask, G. (1971) "A comment, a case history and a plan", in Reichardt, J., Cybernetics, Art and Ideas, New York Graphic Society, Greenwich Connecticut

[14] Pask. G. (1975). Artificial Intelligence : A preface and a theory". In N. Negroponte (Ed.) Soft Architecture Machines.

[15] Pask, G. (1976), *Conversation Theory, Applications in Education and Epistemology*. Elsevier.

[16] Seaman, W. and Rössler, O. E. (2011) Neosentience | The Benevolence Engine. Intellect Books

[17] W. Seaman. "(Re)Thinking — The Body, Generative Tools and Computational Articulation." *Technoetic Arts,* (2010)

[18] Rosen. B. (1991) Life Itself, Columbia University Press

[19] W. Seaman. "The Engine of Engines - Toward A Computational Ecology." *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, 2012).

[20] W. Seaman. "Endophysics and the Thoughtbody Environment, an Outline for a Neo-computational Paradigm." on line publication http://projects.visualstudies.duke.edu/billseaman/pdf/tb_endoNeo-1.pdf (2004).

[21] Seaman, W. (2004) Pattern Flows: Notes Toward a Model for an Electrochemical Computer - The Thoughtbody Environment, Cyberart Bilbao Conference proceedings. see also http://projects.visualstudies.duke.edu/billseaman/pdf/tb_electrochemical-1.pdf(Accessed March 12, 2012)

[22] Müller, A. and Müller, K (2007) An Unfinished Revolution, Heinz von Foerster and the Biological Computer Laboratory, Vienna Edition Echoraum

[23] W. Seaman (2010) "(Re)Thinking — The Body, Generative Tools and Computational Articulation." *Technoetic Arts,* 2010

[24] Seaman has been funded by the Duke Institute for Brain Sciences for the Insight Engine Project:
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.

[25] Diebner, H. and Druckery, T. (2000) Sciences of the Interface, Proceedings of the International Symposium, ISBN 3-930171-26-0 – see also http://on1.zkm.de/zkm/stories/storyReader$1749

[26] Seaman, B. and Rössler, O. E. (2011). *Neosentience | The Benevolence Engine*. London: Intellect Press
[27] W. Seaman. "Endophysics and the Thoughtbody Environment, an Outline for a Neo-computational Paradigm." *on line publication http://projects.visualstudies.duke.edu/billseaman/pdf/tb_endoNeo-1.pdf* (2004).
[28] W. Seaman. "Toward the Production of Nano-computers and in turn Nano-related Emotive Virtual/Physical Environments." *Intelligent Agent 4.2 Spring (online publication)* (2004). [29]
[30] W. Seaman and Andrea Gaugusch. "(RE)Sensing the Observer — Offering an Open Order Cybernetics.." *Technoetic Arts 2.1* (2004).
[31] W. Seaman. "Pattern Flows | Hybrid Accretive Processes Informing Identity Construction." *Convergence Magazine 7.2, special Issue on Intelligent Environments* (2005). [32]
[33] W. Seaman and O.E. Rössler. "Toward the Creation of an Intelligent Situated Computer and Related Robotic System: An Intra-functional Network of Living Analogies." *Emoçào Art.ficial 3.0, Itau Cultural Center Publication* (2006).
[34] W. Seaman. "Unpacking Neosentience / Dystopian Techno-Evolution." *Mutomorphosis (on line publication)* (2007). (http://mutamorphosis.wordpress.com/2009/01/13/unpacking-neosentience/) [35]
[36] W. Seaman. "Unpacking Simultaneity for Differing Observer Perspectives and Qualities of Environment." *Simultaneity*. Edited by S. Vrobel, O.E. Rossler, T., Marks-Tarlow. (2008).
[37] O. Perriquet and W. Seaman. "Art ↔ Science Relationalities." *International Symposium on Electronic Art Proceedings (forthcoming)* (2011).
[38] Rössler, O. E. (1974), "Chemical automata in homogeneous and reaction diffusion kinetics", in Physics and Mathematics of the Nervous System, M. Conraf, W. Güttinger and M. DalCin (eds), Lecture Notes in Biomathematics, vol. 4, Berlin, Heidelberg, New York: Springer-Verlag, pp. 342–69. [39]
[40] Rössler, O. E. (1974), "Adequate locomotion strategies for an abstract organism in an abstract environment", in Lecture Notes in Biomathematics, vol. 4, pp. 342–69. (Equation 13 is the brain equation.)
[41] Rössler, O. E. (1974), "A synthetic approach to exotic kinetics", in, Lecture Notes in Biomathematics, vol. 4, Berlin, Heidelberg, New York: Springer-Verlag, pp. 546–82.
[42] Rössler, O. E. (1978), "Deductive biology – some cautious Steps", Bulletin of Mathematical Biology, 40, pp. 45–58.
[43] Rössler, O. E. (1979), "Recursive evolution", BioSystems, 11, pp. 193–99.
[44] Rössler, O. E. (1981), "An artificial cognitive – plus – motivational system", Progress in Theoretical Biology, vol. 6, New York: Academic Press, pp. 147–60.
[45] Rössler, O. E. (1981), "An artificial cognitive map system," BioSystems, 13, pp. 203–09.
[46] Rössler, O. E. (1985), "An estimate of Planck's constant", in P. Erdi (ed.), Dynamical Phenomena in Neurochemistry and Neurophysics, pp. 16–18. Budapest: Publications of the Central Physical Research Institute. (ISBN 963 372 349 3).
[47] Rössler, O. E. (1996), "Relative state theory – four new aspects", Chaos, Solitons & Fractals, 7, pp. 845–52.
[48] Rössler, O. E. (1996), "Ultraperspective and endophysics", BioSystems, 38, pp. 211–19.
[49] Rössler, O. E. (1998), Endophysics: The World as Interface, Singapore: World Scientific Publishing Co.
[50] Rössler, O. E. (1998), "The world as an accident", in J. Brouwer and A. Broeckman et.al. (eds), The Art of the Accident, NAI Publisher, p. 172.
[51] Rössler, O. E. (2006), Endonomadology, xxxxx23, London. http://1010.co.uk/ottoroesslertranscript.pdf [52]
[53] Rössler, O. E. (2006), Personogenesis – The Toddler's Worked Miracle, http://www.wissensnavigator.com/documents/Personogenesis.pdf. Accessed 30 April 2010.
[54] Rössler, O. E., Rössler, R. and Weibel, P. (1998), "Is physics an observer-private phenomenon like consciousness?" Journal of Consciousness Studies, 5, pp. 443–53.
[55] Rössler, O. E., Lasker, G. E. and Aydin, A. (2004), "Delectatio in felicitate elterius – Benevolence Theory", in G. E. Lasker and K. Hiwaki (eds), Personal and Spiritual Development in the World of Cultural Diversity, vol. 1, pp. 69–78. Windsor, ON, Canada: The International Institute for Advanced Studies in Systems Research and Cybernetics. http://www.lampsacus.com/documents/ROESSLERBENEVOLENCE.pdf
[56] Turing, A.M. (1950). Computing machinery and intelligence. Mind, 59, 433-460.
[57] Koestler, A. (1964), The Act of Creation, New York: Macmillan Co.
[58] Seaman, W. and O. E. Rössler (2011) Neosentience / The Benevolence Engine, Intellect Press ISBN 9781841504049
[59] Seaman, B. (2004) Pattern Flows: Notes Toward a Model for an Electrochemical Computer. Delivered at Cyberart Bilbao 2004. http://projects.visualstudies.duke.edu/billseaman/pdf/tb_electrochemical-1.pdf See also Seaman, B. (2005) Endophysics and The Thoughtbody Environment – An outline For a Neo-computational Paradigm, published on Seaman's website. http://projects.visualstudies.duke.edu/billseaman/pdf/tb_endoNeo-1.pdf
[60] Rössler, O. E. (1974), "Adequate locomotion strategies for an abstract organism in an abstract environment", Lecture Notes in Biomathematics, 4, pp. 342–69.
[61] Rössler, O. E. (1978), "Deductive biology – some cautious Steps", Bulletin of Mathematical Biology, 40, pp. 45–58.
[62] W. Seaman and O.E. Rössler. "Toward the Creation of an Intelligent Situated Computer and Related Robotic System: An Intra-functional Network of Living Analogies." *Emoçào Art.ficial 3.0, Itau Cultural Center Publication* (2006). http://projects.visualstudies.duke.edu/billseaman/pdf/intra-funct.analogies.pdf
[63]Seaman, W. and Verbauwhede, I. The Polysensing Environment (Date Not Set) http://users.design.ucla.edu/~fwinkler/PSE/descr.html and http://users.design.ucla.edu/~fwinkler/PSE/index.html
[64] Seaman, W. and Verbauwhede, I. ***Poly-sensing Environment* - Toward the Development of an Integrated Distributed Technology Exploring Poetic/ Informational Grammars of Attention and Functionality. http://www.fondation-langlois.org/html/e/page.php?NumPage=49 (Accessed March 12, 2013)**
[65] See Suchman, L. (1987), Plans and Situated Actions: The Problem of Human-Machine Communication, Cambridge: Cambridge University Press. See also Agre, P. (1997), Computation and Human Experience, New York: Cambridge University Press.

[66] For other early related approaches see Brooks, Rodney A. and Lynn Andrea Stein. “Building brains for bodies” Autonomous Robots 1: 1, November 1994, pp. 7–25.
[67] Seaman, B. (2005), “Pattern flows | hybrid accretive processes informing identity construction”, Convergence Magazine, Winter, 2005.
[68] Barcelou, (1999), Situated Conceptualization – Chapter to appear in H. Cohen and C. Lefebvre (eds), and Barsalou, Lawrence W. (1999), “Perceptual symbol systems”, Behavioral and Brain Sciences, 22, pp. 577–660.
[69] Charles Spence, http://www.psy.ox.ac.uk/xmodal/. Assessed 30 April 2010.
[70] Peter Cariani, http://homepage.mac.com/cariani/CarianiWebsite/CarianiHomePage.html. Accessed April 2010.
[71] Andy Webster, http://www.andywebster.info/machinista_submission.html. Accessed 30 April 2010.
[72] http://www.informatik.uni-trier.de/~ley/db/indices/a-tree/w/Walther:Marcus.html.
[73] See Lewin, K. (1936), Principles of Topological Psychology, (trans. Fritz Heider and Grace Heider), 1st ed., New York, London: McGraw-Hill, p. 54 – Kurt Lewin in his text Principles of Topological Psychology from 1936 One can potentially join multiple differing topologies together – topological psychological spaces, simulation spaces and physical/actual motion spaces. Lewin discusses how a series of psychological vectors might form a topology. In the chapter entitled The Psychological Life Space As Space In the Sense of Mathematics, he describes how psychological facts can be articulated, ‘connected’ and ‘coordinated’ in a topological space, forming paths – ‘any kind of locomotion of the person in the quasi-physical, the quasi-social, or the quasiconceptual field can be designated as a connecting process which corresponds to a topological patch.’ Lewin further provides remarks about topological space: ‘The fact that certain regions in the psychological environment and within the person influence other regions, both of the environment and of the person, may be taken as a criterion for connectedness in the topological sense.’ This happens through ‘dynamical communication.’ Lewin, 1936.
[74] See von Forester, H. (1962), “Circuitry of clues to platonic ideation”, in Aspects of the Theory of Artificial Intelligence edited by C. A. Muses.
[75] Conversation with Jim Davies.
[76] See O’Keefe and Nadel, (1978), The Hippocampus as a Cognitive Map, Oxford University Press. (although there are new studies on the Hippocampus) See also http://web.mit.edu/9.012/www/Eldridge_NN00.pdf
[77] See Clark, A. (1997), Being There: Putting Brain, Body, and World Together Again, Cambridge, MA: MIT Press.
[78] See de Chardin, Teilhard (1961), The Phenomenon of Man, New York: Harper & Row. See also on a related concept of linked consciousness. See also Ascott, R. (2003), The Telematic Embrace, Berkeley: University of California Press.
[79] Hopkins, Carl D. http://instruct1.cit.cornell.edu/courses/bionb424/students2004/jlf56/general.htm. See also Mittelstaedt, H. (1961), “Control theory as a methodic tool in behavior analysis” (in German), Naturwissenschaften 48, pp. 246–54, p. 248 (1961) and on Holst E. and Mittelstaedt H. (1950), “Das Reafferenzprinzip: Wechselwirkungen Zwischen Zentralnervensystem und Peripherie”, Naturwissenschaften, 37, pp. 464–76.
[80] Gibson, W. (1984), Neuromancer, New York: Ace Books.
[81] Rössler, O. (1973), “A synthetic approach to exotic kinetics”, as found in Lecture Notes in Biomathematics, S. Levin, in M. Conrad, W. Güttinger and M. Dal Cin. (eds), Physics and Mathematics of the Nervous System, vol. 4, Berlin, Heidelberg, New York: Springer-Verlag, pp. 546–82.
[82] W. Seaman. "Unpacking Simultaneity for Differing Observer Perspectives and Qualities of Environment." *Simultaneity*. Edited by S. Vrobel, O.E. Rossler, T., Marks-Tarlow. (2008).
[83] Koestler, A. (1964), The Act of Creation, New York: Macmillan Co. p.36
[84] W. Seaman. "(Re)Thinking — The Body, Generative Tools and Computational Articulation." *Technoetic Arts,* (2010)
[85] Simeonov, P., Brezina, E., Cottam, R., Ehresmann, A., Gare, A., Goranson,T., Gomez-Ramirez, J., Josephson, B., Marchal, B., Matsuno, K., Root-Bernstein, R., Rössler, O., Salthe, S., Schroeder, M., Seaman, B., Siregar, P., Smith, L. (2012) *Integral Biomathics: Tracing the Road to Reality Subtitle: Proceedings of ACIB’11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath’2011 Workshop at ECAL’11, Paris*. Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).
[86]ibid
[87] See Simeonov, P. (2010) Integral biomathics: A post-Newtonian view into the logos of bios, Progress in Biophysics and Molecular Biology 102 (2010) 85e121 (Seaman is referenced)
[88] Simeonov, P., Brezina, E., Cottam, R., Ehresmann, A., Gare, A., Goranson,T., Gomez-Ramirez, J., Josephson, B., Marchal, B., Matsuno, K., Root-Bernstein, R., Rössler, O., Salthe, S., Schroeder, M., Seaman, B., Siregar, P., Smith, L. (2012) White Paper. *Integral Biomathics: Tracing the Road to Reality Subtitle: Proceedings of ACIB’11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath’2011 Workshop at ECAL’11, Paris*. Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).
[89] Seaman, W. The Engine of Engines (2012) in Simeonov, P., Brezina, E., Cottam, R., Ehresmann, A., Gare, A., Goranson,T., Gomez-Ramirez, J., Josephson, B., Marchal, B., Matsuno, K., Root-Bernstein, R., Rössler, O., Salthe, S., Schroeder, M., Seaman, B., Siregar, P., Smith, L. (2012) *Integral Biomathics: Tracing the Road to Reality Subtitle: Proceedings of ACIB’11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath’2011 Workshop at ECAL’11, Paris*. Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).
[90] Stengers, I., (2005) Ecology of Practices and Technology of Belonging, (2005) http://www.imbroglio.be/site/spip.php?article43 . accessed 26 September 2011
[91] Siegelmann, H (1998), Neural Networks and Analogue Computation, Beyond the Turing Limit, Boston, MA: Birkhäuser.

[92] Maclennan, B., (2003) Transcending the Turing Limit, Minds and Machines, Volume 13 Issue 1, February 2003
[93] Penrose, R. (1989), The Emperor's New Mind: Concerning Computers, Minds, and The Laws of Physics, Oxford, UK: Oxford University Press.
[94] Seaman, W. The Engine of Engines (2012) in Simeonov, P., Brezina, E., Cottam, R., Ehresmann, A., Gare, A., Goranson,T., Gomez-Ramirez, J., Josephson, B., Marchal, B., Matsuno, K., Root-Bernstein, R., Rössler, O., Salthe, S., Schroeder, M., Seaman, B., Siregar, P., Smith, L. (2012) *Integral Biomathics: Tracing the Road to Reality Subtitle: Proceedings of ACIB'11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath'2011 Workshop at ECAL'11, Paris*. Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).
[95] von Neumann, J. (1995), The Neumann Compendium, vol. 1, F. Brody and T. Vamos (eds),
Singapore: World Scientific Publishing
[96] von Foerster, H. (1973), "On constructing a reality", in F. E. Preiser (Hg.), Environmental
Design Research, vol. 2, Stroudberg, PA: Dowden, Hutchinson & Ross, pp. 35–46.
[97] Kumar, A. and Mehta, M. (2011) Frequency-dependent changes in NMDAR-dependent synaptic plasticity, Frontiers in Computational Neuroscience
[98] Chang, Jiin-Ju, Joachim Fisch, Friz-Albert Popp, eds. 1998. *Biophotons.* Dordrecht, Netherlands: Kluwer Academic Publishers.
[99] Popp, F. A. (1999) - About the Coherence of Biophotons in "Macroscopic Quantum Coherence"
http://www.stealthskater.com/Documents/Consciousness_31.pdf
[100] Agnati LF, Zoli M, Strömberg I, Fuxe K. (1995) Intercellular communication in the brain: wiring versus volume transmission. http://www.ncbi.nlm.nih.gov/pubmed/8596642 accessed 2 October 2011
[101] Seaman, B. and Verbauwhede, I., (date not set, b) http://www.fondation-langlois.org/html/e/page.php?NumPage=49 accessed 30 September 2011
[102] Seaman, B. and Verbauwhede, I., (date not set) http://users.design.ucla.edu/~fwinkler/PSE/ accessed 30 September 2011
[103] Folowosele, F. (2010) Neuromorphic Systems: Silicon neurons and neural arrays for emulating the nervous system, http://www.neurdon.com/2010/08/12/neuromorphic-systems-silicon-neurons-and-neural-arrays-for-emulating-the-nervous-system/
Accessed 20 October 2011
[104] Computing with Soup, Molecular computing: DNA is sometimes called the software of life. Now it is being used to build computers that can run inside cells. (2012) TheEconomist http://www.economist.com/node/21548488 (Accessed March 12, 2013)
[105] Hagar, A. (2011) http://plato.stanford.edu/entries/qt-quantcomp/ accessed 2 October 2011
[106] Markoff, J. (2010) http://plato.stanford.edu/entries/qt-quantcomp/ accessed 2 October 2011
[107] Seaman, B. and Verbauwhede, I., (date not set, b) http://www.fondation-langlois.org/html/e/page.php?NumPage=49 accessed 30 September 2011
[108] Parrish, D., Hayden, D., Garrett, W. and Huff, R. (1959) Analog Computer Analysis of Flow Characteristics and Volume of the Pulmonary Vascular Bed, Circulation Research 1959, 7:746-752, http://circres.ahajournals.org/content/7/5/746.full.pdf accessed 2 October 2011
[109] Pask, G. (1982), *Micro Man: Computers and the Evolution of Consciousness*, New York: Macmillan,
pp. 133–35.
[110] Kahn, J. (1992) History of electrochemical research at LBL [Lawrence Berkeley National Laboratory] goes way back. http://www.lbl.gov/Science-Articles/Archive/lbl-battery-program-history.html accessed 1 October 2011
[111] Sadeghy, S., and Thompson, M. (2011) Towards information processing from nonlinear physical chemistry: A synthetic electrochemical cognitive system. *BioSystems 102* (2010) 99–111
[112] Blomberg, (2011) Intel Start $4.4 Billion in Chip Venture in New York
http://www.bloomberg.com/news/2011-09-27/ibm-intel-to-invest-4-4-billion-in-new-york-state-nanotechnology.html Accessed 2 October 2011
[113] Brumfield, G. (2011) *Nanocomputers Get Real*, http://www.wired.com/science/discoveries/news/2001/11/48278 accessed 2 October 2011
[114] Whittle, P. (2010) Neural nets and chaotic carriers, London : Imperial College Press ; Hackensack, NJ : Distributed by World Scientific Pub.,
[115] Siegelmann, H (1998), Neural Networks and Analogue Computation, Beyond the Turing Limit, Boston, MA: Birkhäuser.
[116] Simeonov, P. (2010) Integral biomathics: A post-Newtonian view into the logos of bios, Progress in Biophysics and Molecular Biology 102 (2010) 85e121 (Seaman is referenced)
[117] Sharp, P., Cooney, C., Kastner, M., Lees, J. Sasisekharan, R. Yaffe, M. (2011) The Third Revolution: The Convergence of the Life Sciences, Physical Sciences and Engineering. http://web.mit.edu/dc/Policy/MIT%20White%20Paper%20on%20Convergence.pdf (Accessed September 26, 2011)
[118] Angelica, A. (2011) Editor, Kurzweil News, from the AAAS Forum, http://www.kurzweilai.net/convergence-may-lead-to-revolutionary-advances-in-biomedicine-other-sciences?utm_source=KurzweilAI+Daily+Newsletter&utm_campaign=ce83baceb3-UA-946742-1&utm_medium=email
accessed 10 January 2011
Biomatics.org Wiki http://biomatics.org/index.php/Protein_Based_Computing accessed 1 October 2011

Appendix

Otto Rössler on the Brain Equation from the book Neosentience / The Benevolence Engine:

Darwin discovered metabolic adaptation – only sequentially randomly modified metabolic networks can maintain

autonomous self-maintenance in a randomly changing chemicaland physical environment. These permanent changes have to be produced endogenously in sufficient variety. This mechanism can be called “metabolic adaptation” for short. It is very much longer in duration than one generation. Much shorter (momentaneous essentially) changes require a different kind of adaptation. Konrad Lorenz first saw this fundamental difference in a series of conversations we had in 1966. They require “positional” rather than “metabolic adaptation.” Here one can predict that signals and sensors must be involved. Even lowly bacteria living in a tidal region on a shore predictably evolved sensors signaling temporal position in the tidal cycle. This was our first, basic insight: a fundamental second type of adaptation. Chronobiology (which already existed) can be predicted from first principles. The second step was space. When survival depends on position in space rather than in time, positional adaptation in space is predictable. (Moths should eventually show positional adaptation toward candle flames if humans remain a factor in their reproductive success.) Position in space – like momentary position in time – is nothing that can be dealt with by metabolic adaptation. Darwin-style natural selection therefore has to produce sensors. “Positional adaptation in space” through movement is just the next higherdimensional case after positional adaptation in time – chronobiology. What is predictably involved in this twin case is, in addition to sensors, motors. And an intervening transducing network (“brain”).

At this point, it turned out that the newly found situation actually amounts to a wellposed problem in the sense of mathematics. Namely, a “traveling salesman with alarm clocks” problem. For survival-relevant resources of different types may be sharply located in space (like towns to be visited). It is not the minimum overall path that is sought, as in the ordinary travelling salesman of mathematics. Rather, a source (“town”) of the right type – some five or ten – needs to be visited after a certain maximum time interval. Garey and Johnson later re-discovered this special variant to the famous traveling salesman problem of mathematics, calling it an “optimal decision” rather than “optimization problem.” They showed that it is equally “NP complete” as the original traveling salesman problem is. It follows that, if a brain were to solve this well-posed mathematical problem optimally, it would have to be as big and complex as the whole universe is, on purely mathematical grounds. But if the success rate is allowed to be finite (suboptimal), then finite computers suffice – “brains,” that is. Depending on the allowed error rate (defined by the ratio between the maximum mean distance between sources of a given survival-relevant type over the maximum travelling radius allowed by a single “tank filling” of this type), either a very cavalier and haphazard locomotion strategy suffices (like to move at random and never stop, or move at random and stop temporarily whenever in the vicinity of a certain chemical – a type of behavior known to biologists under the name “kinesis”), or a maximally sharply calculated one becomes mandatory to be used. The underlying “computer” (the connecting network between sensors and motors) can stay quite simple as long as the delicacy of the ratio mentioned above is not too great. There then arises a natural threshold here: When pure “direction optimization” (from the momentarily given position in space) is no longer sufficient so that genuine “path optimization” (supralocal optimization) becomes mandatory. Shortly below this threshold, the most sophisticated “local strategy” (of direction optimization) employs a force-field generator of a prescribed structure. This is the “brain equation.” It describes a space- and time-dependent force field. If the task becomes even more difficult – as is eventually unavoidable in evolution, then this suboptimal “local solution” can no longer be appropriate. Nonetheless it can still be used – if it is complemented by a “universal simulator” or virtual reality (VR) machine. This combination of two designs has the asset that a suboptimal fast strategy is still available in case of emergency – if there is not enough time to come up with the supra-locally optimal path-type solution which always takes time. So this is the predictable solution of choice in biology.

A third possibility exists as well: a multiple brain-type solution. The latter is known from “eusocial” animals in biology like ants and naked moles. For this alternative solution, no universal brain equation has been identified up until now.

The above combined machine, the brain equation combined with VR, possesses some interesting predictable design features. They include a pseudo-simultaneous “big screen.” The latter strangely has never been identified or looked for in empirical brain science, nor has an “overlap buffer” and a “late recycler” and a finite-duration “now circuitry.” Nevertheless the most fascinating element remains the force-field generator itself, the brain equation. It combines potentially infinitely strongly attracting and repelling forces emanating from the positions of the closest “sources” of the different survival-relevant types.

All purely endogenously generated. Aristotle knew about them when he wrote that a falling stone is accelerating because it anticipates coming to rest at home. So he already equipped the force field with a VR in his own mind – as is correct not for a falling stone but for an adapted vertebrate.

The most famous constructs of Lonrad Lorenz – “flush-toilet model” of desires, endogenous mood pressure, bonding drive, a neurotransmitter for every type of desire, the relaxed field after a consummatory act, and so forth – all follow predictably from the brain equation but were originally based on field studies and an incredibly perceptive intuition. He said with a resigning tone in his voice that he was not a mathematician. But like Darwin, he did not know that he actually was an outstanding one. Such an equation and brain can be implemented artificially in the new field of Neosentience. But are not all such systems, no matter whether natural or artificial, necessarily of limited intelligence? After all the brain equation has a deterministic structure. The answer is yes. But then how about the human brain – does it make for an exception or does it also involve the deterministic brain equation? It does. It is quite ordinary stuff – sperm whales, elephants, and even corvids have more – the former even very much more – to offer. But are we different? This is correct – we are as a species in general non-autistic. Why is this so? Is it because we are more social, perhaps? It turns out there is a third mode of brain function beside the non-eusocial one described, and the eusocial one. It does not even require a new

anatomy or physiology. The caring one. Lorenz was a deeply caring individual (together with his even greater wife as he admitted). He talked about the joy of bottom-cleaning and nurturing, and said that Sigmund Freud had overlooked bonding as an even stronger drive than eros. Bonding is Lorenz's greatest discovery: That it is a genuine drive, a specific subpotential in the brain equation. Bonding between adults comes and goes in evolution depending on not yet clearly definable properties of the ecological niche. Humans are the pair-bonding apes – besides gibbons. But gibbons do not share nonautism. How did the latter arise in one bonding ape but not the other? It indeed is not bonding alone that is responsible. Most species when newly adopting bonding between adults choose a sexual signal to acquire a new meaning for the new drive. Mounting was chosen by baboons and African wild dogs, for example. Human evolution by accident involved adopting the expression of joyfulness of the satiated infant, the "play face," for bonding. The smile of bonding (greeting) and the laughter of joyfulness miraculously congealed in a single species on the planet and possibly all other life forms in the solar system, the galaxy and perhaps even the universe. It is an extremely unlikely coincidence.

The consequence is a new third type of brain functioning. It arises epigenetically – during the life history of the individual – via the mirroring interaction with the mother, at a quite young age. The consequence is the emergence out of nothing of the suspicion of benevolence in the human toddler. How? Because Mom's happy face looks like her (vitally needed) bonding expression. Laughter and smile look the same.

But let us return to the brain equation and Steven Spielberg's movie "AI." And to the potentially immortal successor of humans – the Neosentient artificial mind that becomes a person through the very same spontaneous act as a toddler does. But this is another
chapter.

Special Thanks goes to Otto Rössler for his friendship, the breadth of his research and on-going conversations.

Professor Bill Seaman PhD, March 13, 2013