Neosentience – A New Branch of Scientific and Poetic Inquiry Related to Artificial Intelligence
Professor Bill Seaman and Otto Rossler

Abstract

Neosentience, a potentially new branch of scientific 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. Rossler, theoretical biologist and physicist, and Seaman, artist-researcher, have been examining the potential of generating an intelligent, embodied, multi-modal 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 approaches are: 1) The generation of artificial minds via parallel processing, in a robotic system. 2) An alternate approach is the generation of an Electrochemical Computer as a robotic system. Biomemetics, 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. The sentient entity is initially modeled on our functional definition of human sentience. The system involves synthetic "drives" as a new element. We seek to articulate the differences to living brains. This transdisciplinary approach necessitates different forms of inquiry are informing this project; Cognitive Science including psychology, education/learning, neuroscience, linguistics, philosophy, anthropology, biology and the arts. We believe this area of research to be of importance.

Neosentience – A New Branch of Scientific and Poetic Inquiry

Central to both the scientific and poetics of Neosentience is to try to abstract the salient qualities of the human self that contribute to the arising of sentience. What are those qualities and what functionalities lead to their arising? A unified approach is attempted including body, brain, mind, environment, and language.

We examine [1] [2] the possibility of abstracting the functional biological systems at operation in the body that enable sentience to arise. We generate this biological abstraction by employing a set of coupled systems derived primarily through analogy to the functionalities of the human counterpart. We present an outline of both system classes and their operational functionalities. The goal is to re-see the body as a functional complex system exhibiting sentience. We abstract qualities from this bio environment to create the neosentient entity[3]. In this light we see the body as a machine of the highest-order complexity nested in a larger environment.

Although computers and the software/hardware paradigm are often compared to the mind/brain, the systems at operation in the human body are of a different order of complexity. The nature of the various inter functionalities of biological processes, are operational in a very different manner to that of the computer. We are interested in developing a new computational model that seeks to reflect how we function as embodied, multifaceted biological systems. This model takes into account how we come to know the world through the integration of time-based pattern flows[4] of multi-modal sense inputs over time. While historically studies of the senses have been kept separate, we are interested in how the senses work together to generate situatedness and environmental understanding. Eventually language and creative functioning will be enabled .[5]

Background

If we look at the history of Artificial Intelligence, one struggles to find a singular coherent definition of intelligence. Instead a pragmatic approach is usually undertaken that is summed up in the following quote by Aleksander and Burnett, drawn from their book *Thinking Machines – The Search for Artificial Intelligence*:

> Rather than becoming embroiled in the controversies which surround the nature of human intelligence, the practitioners of artificial intelligence have generally chosen to define their goals in empirical or operational terms rather than theoretical ones ... The researcher simply chooses a task that seems to require intelligence (playing chess say or recognizing visual images) and tries to build a machine that can accomplish it."[6]

In the same spirit we consider a sentient robotic entity to be a system that could exhibit the following functionalities: It learns; It intelligently navigates; It interacts via natural language[7]; 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[8 9]. 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.

Central to the project is the relationship to human sentience. Biomimetics is a fertile area of study[10]. By abstracting and re-articulating particular operational qualities of the body, we see a new form of sentience arise. We approach it by generating a network of analogies. In the paper *Adequate Locomotion Strategies For An Abstract Organism in An Abstract Environment – A Relational Approach to Brain Function,* Rossler, a long time ago, articulated a top down approach that underlies the first functional implementation. The text describes a special "equivalence class" of bio-functionalities. [11]

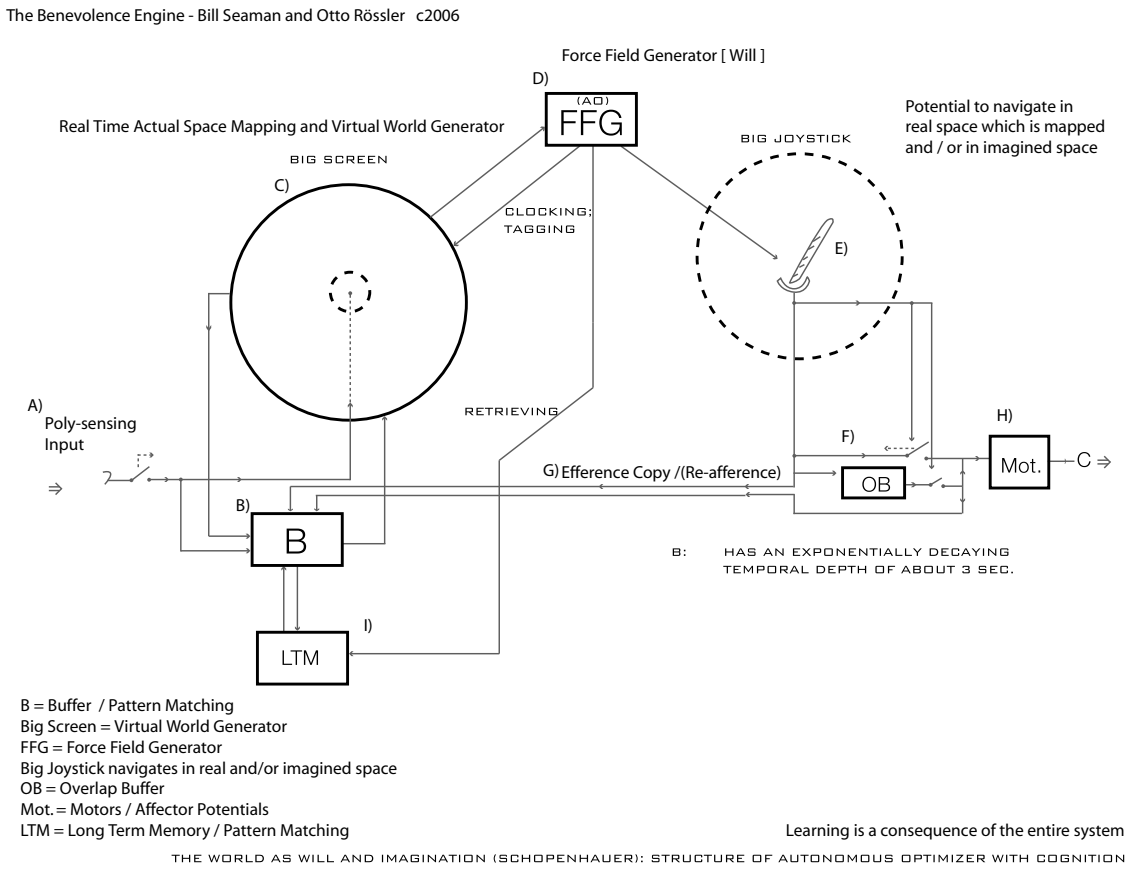
For the sake of playfulness, The N_S.E.N.T.I.E.N.T. paradigm embodies the following salient characteristics :

• **Neosentient** —the system seeks to exhibit sentience of a new variety; (we will elaborate below on how this machine–based sentience would be of itself, having different qualities to that of human sentience).
• **S**elf-organizing – the system is self-organizing[12];
• **E**nvironmentally Embedded – the robotic system should be situated and context aware and/or remotely connected to a situated multimodal sensing system;
• **N**ascent — the system is "brought to life" and learns over time, building up a body of situated knowledge;
• **T**emporal — the system functions in relation to multi-modal time-based flows of differing machine-oriented "sensing" inputs, the parsing of those flows through pattern recognition and operations on those flows (internal abstraction);
• **I**ntra-active — the entity arises through a reciprocal forming with culture and interaction with other individuals. Intra-action may take place with other entities. Because direct input might be facilitated between "entities" and/or in new forms of human/entity communication, I have used the prefix (intra) suggesting a different order of connectivity in communication [distinguishing a property of Neosentience]. The system develops an ongoing "projective" linguistics
• **E**mergent — the entity's actions arise in context and are not known in advance but "come to life" in relation to environmental relations, a series of "emotional" force field attractions and repulsions, and historical intra-actions;
• **N**avigational — it can move about to function in an appropriate manner and becomes context aware across multiple domains;
• **T**ransdisciplinary — the research is informed by and informs multiple disciplines as it become emergently enfolded. As the entity becomes self aware and learns, Neosentience will also be something it leans about, and it may become a participant in it's own discourse of becoming, furthering transdisciplinary discourse in a unique manner.

Diagram of the *The Benevolence Engine*

The Benevolence Engine can be implemented through parallel processing (first in simulated form). We present a flow diagram of the system (Figure 1). This diagram has been composed, drawn from a series of previous papers[13]. One sees a series of functional parts that have been arrived at through the methodology

of deductive biology[14]. We list the main functional parts of the diagram:[15]



A) Poly-sensing Input / Multi-modal; Sensing Systems[16]
B) Buffer / Pattern Matching Mechanism
C) Virtual Reality Generator[17]
D) Force Field Generator (Repulsion and Attraction sliders)[18]
E) Control Driver [internal joystick] / Simulator Mechanism (imagined space)
F) Overlap Buffer
G) Efference Copy / Reafference[19]
H) Motor / Motivation / Movement Potentials
I) Long-term memory

A) Poly-sensing Input / Multi-modal; sensing

The Benevolence Engine begins with a series of input devices — a machine-based multi-modal sensing system.[20] One can imagine one's own senses being abstracted into such a mechanism, although machine-based sensing potentials will potentially be quite different in sensitivity to their human counterparts i.e. one can imagine a system being implemented with infra-red vision. Embodied multi-modal sensing has been discussed by Suchman and Agre.[21] Such multi-modal approaches were initially discussed early on (in the 90's) by people like Brooks[22]. This represents a quite different perspective to earlier AI projects that were not "embodied" and did not see the importance of coming to a deep knowledge of context via multi-modal sensing systems that would be dynamically linked to their environment. Rossler's early papers are unique to the field of AI. Seaman's concept of "Pattern Flows"[23] is discussed in his 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.[24]So has Professor Charles Spence at the Cross-modal research lab, providing significant research into the nature of multi-modal sensing.[25] Peter Cariani has also written at length about

sensing and Temporal Codes[26]. Jon Bird and Andy Webster have also explored related electrochemical sensing topics.[27]

Multi-modal 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 *Benovlence Engine*, it's 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 word in a unique manner.

B) Buffer / Pattern Matching Mechanism

The system would observe in a form of foveal 3D[28], define an updateable map of the environment (by abstracting and simplifying the input), generate 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.

If we think of a human acting in physical space we perform within a layered topological space[29] by superimposing our human emotional space (our feelings, attractions and repulsions to situations and needs) with physical space. Emotional space and physical space can be conjoined or 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/environmental difference. We "build up" knowledge and use it in a projective manner, informing 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 creative combinatoric pattern re-application. Each individual sensed aspect of a linked set of multi-modal memories can lead back to the memory of the original pattern (or constellation of multi-modal inputs) through pattern matching. The system would potentially generate "Platonic" simplifications[30] or averaging[31] — enabling potential recombinant collage-like "creations" built of past relations, mixed with updated information and language (both patterns in their own right).

C) Virtual Reality Generator

The entity is embodied and embedded in the environment. Multi-modal senses provide deep knowledge of the environment that is built up slowly through learning and the inter-functionality of the differing braches of the system 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[32] and depends on the environment for filling in many details for actual embodied experience.[33] 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 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 can not share their mind's eye's vision in a direct manner.[34] Yet in seeking to posit such a new vision system, one must come to study the functionality of the human visual system, and it's 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 multi-modal 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.

D) Force Field Generator (Repulsion and Attraction Drives)

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 evoked. A series of "drives" (internal emotional forces) suggest for us the need to approach and/or avoid differing situations. Our system would house a series of force field sliders that would sum in differing ways related to alternate situations (as well as historical input that is re-associated with the current context through pattern matching, conjoined with current environmental input).This posits a complex systems approach leading to particular behaviors over time. The force field sliders are quantifiable in machine–oriented terms, and controllable/programmable and thus again present a difference between neosentient entities and humans. A neosentient entity might also be emposered to internally re-set their own force field sliders.

E) Control Driver [internal joystick] / Simulator Mechanism (imagined space)

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). Alternately this sends messages to robotic effectors to bring about movement in actual space.

F) Overlap Buffer

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. They 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.

G) Efference Copy / Reafference

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.[35] Thus, the "exafference" forms a relational connection with the entities motion and/or behavior within the environment and the entity's pattern matching, control and simulation mechanisms.

H) Motor / Motivation / Movement potentials

All of the system functioning as a unity define the potential of movement that is directly linked to the environment through the multi-modal sensing system, and the knowledge that has been built up concerning the environment over time.

I) Long-term memory

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.

Discussion

An artificial mind was proposed. It combines many functional ingredients that apparently have not been proposed before, either alone or in combination. The "big screen " is a full fledged virtual reality in the sense of William Gibson[36]. There is an updating involved that automatically generates a natural frequency of "nowness" re-generation. It would not make sense to have an updating rate that is much faster than locomotion and limb movement requires. 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 in concert with the programmed "drives". This is done via the "big joystick" which is directly "pulled" by force centers in the environment. The machine would be completely automatic were it not for the capability of closed eye locomotion. Here, the clash of some simultaneous forces acting on the joystick immobilizes it momentarily, while giving control 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.

But, if two such machines interact in a cross caring manner, each can be stopped in an attempt to simulate in favor of the other's goals. In this case, the invention of an 'hallucinated other center of optimization' occurs. This is the invention of "benevolence". This presents a much more interesting mode of functioning of the system then simple locomotion. It will be necessary to build two such machines to enble 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 unconsiousness identity through the emergence of a simulated existence that is benevolent, toward another simulated consciousness, also internally represented by the same system. So strangely, consiousness is not implied in the machine itself but only in a kind of paranoic creation out of nothing within the machine. The ghost of consciousness has no substratum in the hard or software of the system. It is pure fiction but it is the only agent to be found.

We apologise that we have run ahead a little bit in the description of the system. Once the machine is ready for inspection and observation in interaction with another machine or a human partner, more details about it's secrets will become available. The above interpretation of our machine presupposes to some extent that the reader is familiar with the descriptive work of Ape Psychology found for example, in the recent book *Our Inner Ape* by Frans de Waal.

Summary

Neosentience is a new area of scientific 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. It must be noted that any sentient entity that might be generated, modeled on our functional/operational definition of sentience, would have a set of qualities foreign to human sentience. In particular the differences would be related to qualities of embodiment, sensing, communication channels, networking, and the synthetic drives. Instead of ignoring the differences between a "sentient machine" and human sentience, we seek to articulate these potential differences clearly. Articulating the operative nature of Neosentience is related to invading neighboring fields like psychoanalysis and ethics, not to mention the art of imagining other souls.[37]

Special Thanks goes to Jim Davies for feedback on the paper and to Peter Cariani for conversations surrounding the topic.

[1] Seaman, working as an artist/researcher has explored the related topic of meta-meaning production as a poetic goal in his historical research. Informed and inspired by the ongoing research dialogue with Rossler, Cariani and others, Seaman has been creating a series of Artworks/installations. — A Video Tape with an extensive poetic text by Seaman – *The Thoughtbody Environment / Toward A Model for an Electrochemical Computer*; A series of Photo/Text images; A set of short Haiku-like techno/poetic texts — *The Thoughtbody Interface,* [1] and the development of a proposal for a relational multi-modal database to house both the scientific research surrounding this project as well as aspects of the poetic work[1]. Seaman is collaborating with D. Howe on a *Bisociation Engine* project as well. Thus deep art/science creativity is explored in the service of entertaining the problem by exploring diverse sensibilities, processes and methodologies.

[2] Rossler, Otto, *Adequate LocomotionStrategies For An Abstract Organism in An Abstract Environment – A relational Approach to Brain function,* as found in **Lecture Notes in Biomathematics**, Managing Editor S. Levin, #4, Physics and Mathematics of theNervous System edited by M. Conrad, W. Gottinger, and M. Dal Cin., Springer-Verlag, Berlin, Heidelberg, new York.1973, p. 342 - p. 369

[3] In particular, electrochemical processes will be entertained related to research toward the *Thoughtbody Environment* in a subsequent paper. See Rossler's seminal paper — Rossler, Otto, 1973, *A Synthetic Approach to Exotic Kinetics*, as found in **Lecture Notes inBiomathematics**, Managing Editor S. Levin, #4, Physics and Mathematics of the Nervous System edited by M.Conrad, W. Gottinger, and M. Dal Cin., Springer-Verlag,Berlin, Heidelberg, new York, p. 546 - 582

[4] Seaman, B., *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*, Convergence Magazine, Winter, 2005

[5] See also Suchman, Lucy A. 1987. *Plans and Situated actions: The problem of human-machine communication*. Cambridge: Cambridge University Press.

[6] Aleksander, I. and Burnett, P. 1987. *Thinking Machines – The Search for Artificial Intelligence*. New York: Alfred A. Knopf.

[7] See Steeles, Luc, http://arti.vub.ac.be/steels/publications.html

[8] See Lorenz, K. 1977. *Behind the Mirror: A Search for a Natural History of Human Knowledge,* New York : Harcourt Brace Jovanovich Translated by Ronald Taylor

[9] See Elephants Frans de Waal PNAS, Sept. 2006

[10] See Bar-Cohen, Yoseph and Breazeal, Cynthia, 2003. *Biologically Inspired Robots*, SPIE Press, Washington

[11] Rossler, O. 1973a *Adequate Locomotion Strategies For An Abstract Organism in An Abstract Environment – A relational Approach to Brain function,* as found in **Lecture Notes in Biomathematics**, Managing Editor S. Levin, #4, *Physics and Mathematics of the Nervous System* edited by M. Conrad, W. Gottinger, and M. Dal Cin., Springer-Verlag, Berlin, Heidelberg, new York. 1973, p. 342 - p. 369

[12] See http://www.calresco.org/sos/sosfaq.htm#1.1 for a definition of self-organizing systems.

[13] Rossler, O. 1973. *Chemical Automata In Homogeneous And Reaction Diffusion Kinetics,* as found in **Lecture Notes in Biomathematics**, Managing Editor S. Levin, #4, *Physics and Mathematics of the Nervous System* edited by M. Conrad, W. Güttinger, and M. Dal Cin., Springer-Verlag, Berlin, Heidelberg, new York, p. 417

Rossler, O. 1973a, *Adequate Locomotion Strategies For An Abstract Organism in An Abstract Environment – A relational Approach to Brain function,* as found in **Lecture Notes in Biomathematics**, Managing Editor S. Levin, #4, *Physics and Mathematics of the Nervous System* edited by M. Conrad, W. Gottinger, and M. Dal Cin., Springer-Verlag, Berlin, Heidelberg, new York. 1973, p. 342 - p. 369

Rossler, O. 1973c, *A Synthetic Approach to Exotic Kinetics,* as found in **Lecture Notes in Biomathematics**, Managing Editor S. Levin, #4, *Physics and Mathematics of the Nervous System* edited by M. Conrad, W. Gottinger, and M. Dal Cin., Springer-Verlag, Berlin, Heidelberg, new York, p. 546 - 582

Rossler, Otto, 1981, *An Artificial Cognitive-plus-Motivational System*, Progress In Theoretical Biology, Volume 6, Academic Press Inc.,

Rossler, O. 1981b, *An Artificial Cognitive Map System*, BioSystems, 13 (1981) p. 203-209

Seaman, Bill, 2004 *Pattern Flows: Notes Toward a Model for an Electrochemical Computer — The Thoughtbody Environment*, delivered at the Cyberart Bilbao, Conference, proceedings also available at billseaman.com

Seaman, Bill, 2005, *Endophysics and The Thoughtbody Environment – An outline For a Neo-computational Paradigm*, billseaman.com

Seaman, B., *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*, Convergence Magazine, Winter, 2005

Seaman, Verbauwhede, Hansen, 2004 http://students.dma.ucla.edu/~fwinkler/PSE/

[14] Rossler, O. 1978. *Deductive Biology: Some Cautious Steps*. Bulletin of Mathematical Biology. Springer New York, Volume 40, Number 1, January 1978 p. 45-58
http://www.springerlink.com/content/f87752853qhh4725/

[15] See http://billseaman.com/, Seaman and Rossler, *Toward The Creation of an Intelligent Situated Computer and Related Robotic System: An Intra-functional Network of Living Analogies*.

[16] Seaman, Verbauwhede, Hansen, 2004 http://students.dma.ucla.edu/~fwinkler/PSE/ (for an "environmental" approach to bundled sensing. See also MEMS – Micro-Electro-Mechanical Systems (MEMS)

http://www.memsnet.org/mems/what-is.html

[17] See Rossler, Otto, *An Artificial Cognitive MapSystem*, BioSystems, 13 (1981) p. 203-209

[18] Rossler, Otto, 1981, *An ArtificialCognitive-plus-Motivational System*, Progress In **Theoretical Biology**, Volume 6, Academic Press Inc

[19] Hopkins, Carl D.http://instruct1.cit.cornell.edu/courses/bionb424/students2004/jlf56/general.htm
See also Mittelstaedt, H.: *Control Theory as a Methodic Tool in Behavior Analysis* (in German), Naturwissenschaften 48, 246-254, p. 248 (1961) and on **Holst** E, **Mittelstaedt** H. (1950) Das Reafferenzprinzip: Wechselwirkungen Zwischen Zentralnervensystem und Peripherie. Naturwissenschaften 37: 464–476

[20] See also MEMS – Micro-Electro-Mechanical Systems (MEMS)
http://www.memsnet.org/mems/what-is.html See also Seaman, Verbauwhede, Hansen, 2004, http://students.dma.ucla.edu/~fwinkler/PSE/ for an environmental approach.

[21] See Suchman, Lucy A. 1987. *Plans and Situated actions: The problem of human-machine communication*. Cambridge: Cambridge University Press. See also Agre, Philip E. 1997. *Computation and Human Experience*. New York, NY: Cambridge University Press.

[22] For other early related approaches see Brooks, Rodney A. and Lynn Andrea Stein."Building Brains for Bodies" Autonomous Robots (1:1), Nov. 1994, pp. 7-25.

[23] Seaman, B., *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*, forthcoming Convergence Magazine, Winter, 2005

[24] See Barcelou, *Situated Conceptualization* – Chapter to appear in H. Cohen & C. Lefebvre (Eds.), and Barsalou, Lawrence W. , *Perceptual Symbol Systems* in BEHAVIORAL AND BRAIN SCIENCES (1999) 22, 577–660 Handbook of Categorization in Cognitive Science. St. Louis: Elsevier

[25] http://www.psy.ox.ac.uk/xmodal/

[26] http://homepage.mac.com/cariani/CarianiWebsite/CarianiHomePage.html
Cariani has also shown his interest in Pask's Electrochemical studies. Cariani and I have spoken at length about these topics.

[27] http://www.andywebster.info/machinista_submission.html

[28] See the following related systemshttp://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=546136 and http://hal.inria.fr/view_by_stamp.php?label=INRIA&action_todo=view&langue=fr&id=inria-00074004&version=1 and more recently http://www.informatik.uni-trier.de/~ley/db/indices/a-tree/w/Walther:Marcus.html

[29] See Lewin, K, 1936, *Principles of Topological Psychology,* translated by Fritz Heider and Grace Heider, 1st edition, New York and 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 quasi-conceptual 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

[30] See von Forester, H., *Circuitry of Clues to Platonic Ideation*, in *Aspects of the Theory of Artificial Intelligence* edited by C. A. Muses.

[31] Conversation with Jim Davies

[32] See O'Keefe and Nadel, 1978. *The Hippocampus as a Cognitive Map*, Oxford University Press

[33] See Clark, A., 1997. *Being There: Putting Brain, Body, and World Together Again*. Cambridge, Mass. : MIT Press,

[34] See de Chardin, Teilhard 1955, *The Phenomenon of Man*, New York : Harper & Row, 1961, c1959 on a related concept of linked consciousness. See also Ascott, Roy, 2003. *The Telematic Embrace*, Berkeley : University of California Press

[35] Hopkins, Carl D.http://instruct1.cit.cornell.edu/courses/bionb424/students2004/jlf56/general.htm
See also Mittelstaedt, H.: *Control Theory as a Methodic Tool in Behavior Analysis* (in German), Naturwissenschaften 48, 246-254, p. 248 (1961) and on **Holst** E, **Mittelstaedt** H. (1950) Das Reafferenzprinzip: Wechselwirkungen Zwischen Zentralnervensystem und Peripherie. Naturwissenschaften 37: 464–476

[36] Gibson, W. 1984. *Neuromancer*. New York: Ace Books.

[37] See DE Waal, Frans, 2005 *Our Inner Ape*, Riverhead/Penguin, New York