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(Re)Thinking – the body, generative tools and computational articulation

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The body

We will consider the body as a complex adaptive system, far from equilibrium – an environment actively nested within a larger environment. The body can be understood as an open system – changing subtly in an ongoing relation to new knowledge, new technologies, new linguistic definitions, biological change over time, and new forms of relationality to other beings, organisms and environmental factors. We seek to understand what is at operation in the body that leads to thinking, and in a larger sense, leads to our human sentience. In this sense we seek to understand the body as a complex intra-active system of systems that can be articulated from the vantage points of many different disciplinary perspectives, given the complexity of our being. We will view the body as an ultra-complex adaptive unity from the perspective of an 'Open Order Cybernetics'. Here we are interested both in thinking as an embodied process and (re)thinking the body as a multivalent entity. Also, we are understanding the importance of many different qualities of human/machine processes and how these extend our senses and human abilities in new ways, enabling us to further articulate the body's entailments as an ongoing endeavour. We will define the notion of 'entailment' to be all causal processes that are at operation in the body. In particular, we are interested in how these processes intra-act with each other in a dynamic manner over time, contributing both directly and indirectly to ongoing thought processes and human change.

A multi-perspective approach to understanding that which is at operation in the body contributing to thought

We can examine the body from a series of different disciplinary, interdisciplinary and transdisciplinary perspectives – scientific, humanities-related, and poetic. Often new knowledge arises in the space between established domains, informed by defining new forms of dynamic relationality. If we unpack the conceptual processes we undertake as creative thinkers that eventuate in new modes of understanding, could we create a new tool set informed by this plethora of processes, authored to augment our current approach to knowledge production? Could we create a computational 'tool of tools' comprised of many digital tools and processes that might be authored to intra-act in a thought augmenting manner? We will call this system an 'insight engine'. More specifically we have named this 'engine' the 'Thoughtbody Nexus'. One concept engendered by the 'insight engine' is to employ systems that enable us to explore multiple disciplinary perspectives through 'intelligent' dynamic juxtaposition of relevant information to facilitate informed discussion and debate. We seek to achieve this by creating a singular multi-functional interface enabling one to access a multitude of distributed digital processes, bringing different 'perspective' domains into juxtaposition via user (and machine driven) interaction. Accessing this information and discussing/analyzing data from differing disciplinary perspectives (and/or adding new information) can in turn potentially help us to define qualities of relationality between these different perspectives, as well as to articulate relevant methodologies, and specific language inherent to each differing field of study. We can also seek to develop common language enabling us to bridge disciplinary domains in a relevant manner through articulate negotiation of linguistic and related media-object potentials. Another overarching function seeks to facilitate informed searches to find relevant papers, books, visualizations, simulations, emulations, media-objects and processes, as well as related historical developments.

Leveraging distributed services within the 'Insight Engine'

We seek to engage in part with high-level information systems that have already been developed (or that are currently being developed). In this light it is interesting to note work done by such organizations as the *Concept Web Alliance*. They employ a method called the computational 'triple' – 'A triple is comprised of two concepts and an explanation of the link between these two concepts, much like a sentence with a subject, object and predicate'. (Marx, 2009, http://conceptweblog.wordpress.com/conferences/) We can imagine leveraging existing computational systems like *The Concept Web* as one of many 'links' to networks of micro-processes available for juxtaposition in the 'function-windows' of our 'insight engine'. *The Concept Web Alliance* is an international non-profit organization aimed at harnessing 'semantic web' approaches to corral life-science data. CWA's eleven founders aim to pull together existing academic projects, as well as seek new ideas and methods, to address the challenges associated with high-volume scholarly and professional data production, storage, interoperability and analyses. Where the *Concept Web* is currently focused on a particular scientific realm of data access, our approach is a multi-perspective one, bringing scientific data from disparate research fields and scientific approaches together with related non-scientific information in the service of insight production arising out of 'associative' processes.

Another organization that might be explored via the 'insight engine' is the *OSKIMO* project – *Open Knowledge Simulation Modeling*. *OKSIMO* delivers professional support, consulting, and training for testing a proof of concept, deploying a simulation, or developing knowledge simulation models. We imagine such a domain to populate one 'function-window' in our overarching 'conglomerate' media space – imagine many differing algorithmic functionalites ('function windows') brought into dynamic juxtaposition. These 'context-windows' can be opened up and examined in detail, juxtaposed, potentially saved as a cross-referenced snapshot of process, and/or automated/updated via intelligent agents (I will discuss this in more detail below). Given our access to this new 'nexus' of tools and processes, we can augment our ability to articulate bodily 'entailment' and also inform study related to differing aspects of the sciences and the humanities. Such an undertaking can also inspire new computational artistic approaches and methodologies. Imagine a generative wall, always suggesting dynamic associations as a new form of 'conceptual' public art.

Dynamic interaction with such an extended system might potentially lead to new knowledge through focused process-oriented combinatorics. In addition one micro-contextual 'tool' might 'inform' the other tools of what it is 'interested in' via intelligent agents, new forms of artificial intelligence and particular employment of meta-tags (a linguistic framing methodology that enables computational reorganization to be automated).

Where historically I have explored Recombinant Poetics in my practice, we now move to *Recombinant Informatics* – the combination and recombination of differing informational contexts in the service of insight production. We seek to computationally author informed approaches to the creation of this 'nexus' of micro-contexts (multiple computationally derived contexts that are explored in relation to one another). This interface could also facilitate distributed video conferencing and group discussion, blogs, wikis, etc. Process-oriented 'trails' and 'mark-ups' of ongoing processes could also be articulated in relation to the exploration of individual micro-contexts, their combination and recombination. Imagine that a network of juxtaposed contexts might be recalled at any given moment, pointing toward the predilections of a particular group of researchers. One could also call up a network of relations and then juxtapose this to a differing network, or individually explore particular subprocesses. Given the vast complexity of the subject and the current limits of computational approaches to fully entailing bodily processes, we imagine this 'tool of tools' to be an open, ever-expanding system. In particular, multiple recursive loops could contribute to new inter- and intra-contextual understanding.

Computers began as people

'Computers' were initially people before they were understood as non-human machines given the history of the use of this word. In *An Illustrated History of Computers* John Kopplin states :

> 'Computer' was originally a job title: it was used to describe those human beings (predominantly women) whose job it was to perform the repetitive calculations required to compute such things as navigational tables, tide charts, and planetary positions for astronomical almanacs'.
>
> (Kopplin, 2002, http://www.computersciencelab.com/ComputerHistory/History.htm)

It is interesting to note that the etymology of the term computer began with 'Computare' and focused on reconning:

> Compute 1631, from French, computare 'to count, sum up' from com 'with' + putare 'to recon'. The term was initially used for a person who 'computes' 1646; mechanical calculating machine, 1897; and electronic machine, 1941. In the modern meaning, 'programmable digital electronic computer' 1945 (the

theoretical sense is from 1937, as in the Turing Machine). (Harper, 2001, http://www.etymonline.com/index.php?search=computer&searchmode=none)

So we ask, what are all of the processes at operation in the body that enable us to 'recon'? The body is extremely complex and we can approach it from many different disciplinary understandings. Individual disciplines often have their own language, publishing domains, and intellectual hegemonies. How can we facilitate interdisciplinary and transdisciplinary insight through computational means? From the perspective of biochemistry intersecting with computer science we can come to understand the body as an 'electrochemical' computer – a far from equilibrium complex adaptive system.

The articulation of a bio-mimetic form of computation

In the above light, the future understanding of the body's entailments as they are related to thought processes, could lead to a re-understanding the nature of computation itself. The terms 'Computational Articulation' in the title of this article, have two different readings – one explores the use of computers to discuss, brainstorm and further entail the functionality of the body as related to thought processes; the second approach explores the use of this entailment to re-understand and articulate computation as a bio-mimetic and bio-abstracted set of foci.

Human computation

The unpacking of current notions of computation could potentially be redefined in relation to the actual bio-functionality of the human body, and thought in particular. From this vantage point we could functionally shift our focus from what current computation is, to a new perspective of what this particular branch of computation might become through deeper understanding of human thought processes and the entire body's relation to those processes.

In a text entitled *Cracking the Neural Code, Discovering the Language of the Brain*, the research of Garrett Kenyon was discussed. (Gardner, 2009, https://sfcomplex.org/wordpress/2009/07/brain-language) The text stated that he was one researcher exploring aspects of this field in his work at Los Alamos National Laboratories employing a new Roadrunner supercomputer at LANL, as a member of the PetaVision Synthetic Cognition project. The article states that Garrett and others are driving the expansive power of this computer to mimic complex neurological complexes in an effort to posit a 'Rosetta Stone' for the language of the brain. In particular Kenyon is researching the bio-functionality of vision. In a biographic text discussing his work on the Lifeboat Foundation site, it states: 'Simulating large, semi-realistic neural systems will clearly require massive computational resources. We are developing a suite of object-oriented tools that will allow any neural simulator to (take) maximum advantage of high-end computer clusters'. (Kenyon, 2009, http://www.lifeboat.com/ex/bios.garrett.t.kenyon) [Varified by Seaman in email discussion with Kenyon].

We ask, how can we employ knowledge gleaned from Kenyon's (and others) research and apply it to articulate a new definition of computation? In terms of research into aspects of analogue computing that are relevant, Hava Segelmann (Segelmann, 2007, http://binds.cs.umass.edu/anna_cp.

html) is exploring analogue neural networks and new forms of analogue computation. She provides her unique point of view:

> While theoretical computer science has historically rested upon the hitherto unquestioned assumption that computers are discrete, static machines (as in the classical Turing model), the nervous system, having 10^{14} synaptic connections that adapt with experience, should not be conceived as a static algorithm, and the chemical and physical processes affecting the neuronal states are not discrete. The new analog networks have captured these two properties. In the most general terms, analog neural models consist of assemblies of simple processors, or 'neurons', operating in parallel, where each computes the continuous scalar activation function of its input, and affects its neighbors in proportion to the adaptable 'weight' number associated with the directed link between them.
>
> (Segelmann, 2007, http://binds.cs.umass.edu/anna_cp.html)

Segelmann states that 'The surprising finding has been that when analog networks assume real weights, their power encompasses and transcends that of digital computers'. She goes on to say 'our model captures nature's manifest "computation" of the future physical world from the present, in which constants that are not known to us, or cannot even be measured, do affect the evolution of the system' (Segelmann, 2007, http://binds.cs.umass.edu/anna_cp.html). Developing a relevant analogue system that is informed by the biological systems at operation within us is important in that it can perhaps embody and bring to light a unique set of qualities that are not inherent to electronic computers.

An embodied relation to environment contributing to knowledge production

Along with individual brain functionalities, an even more complex long-term set of problems can be articulated in relation to our relationship to environment. In particular, multi-modal sensing, embodied learning and the full entailment of thought processes can be further studied to reveal many currently unknown factors. This new 'perspective of perspectives' suggests the birth of a contemporary transdisciplinary research paradigm related to biomimetics. Such a perspective is daunting given the computational complexity needed to emulate such processes in terms of reflecting the actual complexity of environment/body/brain intra-actions – in particular, exploring that which is at operation in sensing and human 'reconning'. Coming to know the world from the enfolding of many different intellectual perspectives over time exhibits great complexity, especially when the senses are studied as intra-functional inputs. Yet, time is long. The electronic computer has continuously gained speed and their potentials are changing constantly so one must look toward working on this problem as a long-term initiative, creating new tool sets as Kenyon is doing and enfolding multiple approaches as in our 'insight engine'.

One imagines exploring the intra-functionality of analogue and digital systems, given the differing strengths of each. It is interesting to note that Kenyon (discussed above) sees an important relation to embodied experience of the environment in relation to memory. He suggests in his text

Currently Active Research Topics: 'The problem of storing memories over long periods, despite random fluctuations in individual synaptic weights, can thus be solved by exploiting the structure present in the environment itself' (Kenyon, 2009, http://www.lifeboat.com/ex/bios.garrett.t.kenyon) [Originally found on Kenyon's website – http://sites.google.com/site/garkenyon/]. Andy Clark (1997) has also discussed leveraging our relation to the environment in his text *Being There, Putting Brain, Body and World Together Again,* Clark states: 'In place of the intellectual engine cogitating in a realm of detailed inner models, we confront the embodied, embedded agent acting as an equal partner in adaptive response which draws on the resources of mind, body, and world'. Our complex multi-perspective approach must keep in mind the reciprocal relation to others and the environment, as learning is undertaken and memory is employed, including linguistic framing, as well as social and cultural perspectives as they are enfolded into the production of knowledge built up over time.

One major difference of human computers to that of electronic computers is that humans show a deep contextual understanding to their studied subjects, enfolding a 'knowing' and informed relationality to multiple and shifting contexts in the production of thought. Humans build up an understanding of environment through multi-modal sensing, learning, multiple forms of logic etc., as well as by employing distributed technological processes and relationality to media exchanges as part of knowledge production. Yet the machinic realm is currently being extended through differing approaches to synthetic sensing and computational approaches to contextual 'understanding'. Perhaps, the most profound question that one can ask is: 'what is at operation biologically in the human computer that enables us to achieve contextual awareness and understanding?'

Grier (2005), in *When Computers Were Human,* discusses the relationality of the *human computer* to that of the machine.

> The story of the human computer is connected to the development of the modern electronic computer, but it does not provide the direct antecedent of the machines that were built for scientific and business calculation in the last half of the twentieth century. To be sure, the two stories twist about each other, touching at regular points and sharing ideas with the contact. The developers of electronic computers often borrowed the mathematical techniques of hand calculation and, from time to time, asked human computers to check some number that had been produced by their machines; however, few human computers contributed to the invention of electronic computing equipment, and few computing offices were connected to machine development projects.
>
> (Grier, 2005, p. 7)

So the 'genealogy' of contemporary electronic computers we employ today, having first been modelled in part after functional aspects of calculation, and a particular set of the 'reconning' pursuits of the 'human' computer, has later been extended in functionality toward aspects of calculation that machines might do 'better' than human computers. Artificial intelligence is another field that has long sought to model aspects of human intelligence. The potential to design new computers based on biomimetic study is a central pursuit of this current research. Perhaps there is a key to human creativity that has yet to be articulated, thriving in the complex biological substrate of our human bio-functionality. Could we imagine collaborating with a new variety of 'creative' bio-computer based on 'Neuromorphically' articulated creative system, to augment human creativity?

> Neuromorphic systems are implementations in silicon of sensory and neural systems whose architecture and design are based on neurobiology. This growing area offers exciting possibilities, such as sensory systems that can compete with human senses and pattern recognition systems that can run in real time. It is at the intersection of neurophysiology, computer science and electrical engineering.
>
> (Smith and Hamilton, 1998, back cover)

For those that feel that the analogue system does not have the desired accuracy and determinacy, the neuromorphic approach may be of greater value. Here, research can bifurcate and be applied to both analogue and digital realms although we are more interested in the emergent properties that our embodied electrochemical system can make manifest.

Historical biological relations to computation

In 1842, Ada Lovelace posited the notion that a particular variety of machine could be used to explore operative aesthetic processes. She imagined the potential creative use of machines with the notion that machines might come to compose music and/or explore different kinds of 'operational' processes.

McCulloch and Pitts (1943) paper entitled *A Logical Calculus of the Ideas Immanent in Nervous Activity* defined an initial approach to the generation of a synthetic neuron. This approach has enabled a huge body of research in relation to neural networks. I am seeking to (re)think and extend this approach. McCulloch and Pitts' formulation of the artificial neuron in the early 1940's sparked the birth of a new field, where one focused aspect of human bio-functionality could potentially be simplified and abstracted in the service of the creation of machines that might have thinking-like properties.

Turing's (1990) writing on the potential of situated intelligent machines with 'input' and 'output' organs and his early articulation of the potentials of the field, in *Computing Machines and Intelligence* are precursors to our 'extended' embodied approach. The 'Universal Machine' as articulated by Turing presents the computer as an open device – where the functionality of the machine can be focused in many ways. Yet, will seeing the body as an electrochemical computer make us change our understanding of what computation is? We are still at the beginning of fully entailing the mechanisms and bodily processes involved in thought production. Our systematic reverse-engineering of thought is still far from being fully 'articulated' and may never be fully defined.

John von Neumann (1995) adopted the McCulloch and Pitts' symbolism in diagramming the logical structure of the proposed computer, and introduced terms such as organ, neuron, memory … conceptual 'analogues' of the human computer's bio-functionality. From a biological point of view our understanding of computation and its conceptual articulation might need to be rethought, given our current and ever growing knowledge of bodily processes and new approaches to defining and articulating the 'language of the brain'. Here we point to our title – '(Re)Thinking – The Body, Generative Tools and Computational Articulation'. Interestingly, analogue computers were of great interest to people like Vannevar Bush (best known for his ideas surrounding the Memmex) at MIT (Nyce and Kahn, 1991). Bush's Differential Analyzer was an important 'mechanical' analogue machine:

> The Differential Analyzer was an analog device that was reported to be the most accurate calculating device of its time. The Differential Analyzer was based on metal rods and gears. [remove]There were eighteen shafts that ran lengthwise through the machine.
>
> (Greenia, 2000, http://www.computermuseum.li/Testpage/Differential-Analyzer-1931.htm)

So we must also remember that analogues of bodily processes may take many forms, some more mechanical than biological. In their study of Vannevar Bush's article *As We May Think*, Nyce and Kahn (1991) discuss Bush's wish to explore new kinds of machines for managing information and representing knowledge, as well as building trails of association. The Memex was to include an imaging storage system – high resolution microfilm reels (akin to apects of human memory); a dynamic viewing system for sharing stored artifacts – his system was to be coupled to multiple screens, addressable by multiple viewers; and an image acquisition technology (like the human sense of vision) cameras; the system was to be controlled by electromechanical means. Like Bush, we are interested in augmenting human association, as well as exploring new approaches to representing knowledge, housing imagery, sharing information and ideas, and using the system to articulate traces (memory of process). Our proposed 'insight engine' could be designed to form operative connections to networks of stored media elements and processes in the service of brainstorming our research into human computers. Such a system may also help us define new technological advances in the service of creating other new technologies. We extend Bush's ideas via the employment of multiple functional algorithmic micro-processes presenting differing forms of media elements, media processes and media experiences, including the potential to explore poetic experience, all functioning as catalysts for knowledge production.

Analogue computing was all but discarded by Von Neumann in the service of accuracy and the elimination of 'noise'. He states: 'It seems clear, however, that digital (in the Weiner-Caudwell terminology: counting) devices have more flexibility and more accuracy, and could be made much faster under present conditions' (Neumann 1995: p. 497). Yet, isn't the human computer special in its 'creative' and 'poetic' abilities? What is at operation biologically that enables such human capabilities? We must also focus here on 'sensing' and the contextual building up of environmental knowledge through the body. This embodied approach to artificial intelligence was pushed out of the equation for many years. Also – is there something special about the body and its employment of 'noise' and 'chance' in creative thought processes?

Artificial Intelligence was coined in a conference at Dartmouth in 1956 by John McCarthy. In 1958 John McCarthy and Marvin Minsky founded the Artificial Intelligence Laboratory at MIT. (Kurzweil, 1990, http://www.kurzweilai.net/meme/frame.html?main=/articles/art0298.html) Minsky wrote many books on the subject. *Society of Mind* (1986) discusses the notion of 'Agents' – microprocesses that are unintelligent in themselves but are emergent in nature when interacting, enabling 'intelligence' to arise. New approaches to the creation of 'intelligent agents' (mentioned above) could enable exciting forms of combinatorial relations, giving each unique user-driven exploration a differing emergent outcome.

Poetic and aesthetic steering

As an artist exploring aspects of the database aesthetic, along with the conceptual art foci that this research embodies, such informational 'materials' might also be juxtaposed in more poetic and aesthetic ways through differing interface choices, given the exploration of multiple interactants. The system could be designed such that it could be 'steered' toward multiple functionalities, borrowing from the etymology of Cybernetics – 'Steersman'. One could also juxtapose poetic and scientific functionalities of the device and drive it toward purely scientific results or alternatively, use it for entirely artistic ends.

Vast complexity

There are said to be as many as 10,000 different kinds of neurons in the brain – having subtly different functions related to different areas in the brain as well as in relation to more global brain functionalities. To this we add that there are 200 billion neurons in the brain. We must also consider the complex bio-functionality of the senses. How might dynamic hierarchies and/or heterarchies be visualized in new ways that illuminate their intra-functionality? Can we develop new computational systems to reflect such complex bio-landscapes by bringing different domains and scales of research into play? As computer-based systems and technological sensory extensions change our relation to both nature and language, we need to create mechanisms that function at the highest possible level of human/machine interaction, to best reflect upon this complicated plethora of emergent relations. In so doing we change the sensing and knowing potentials of the organism itself through machinic extension.

Douglas Engelbart (1962), stated: 'By augmenting human intellect we mean increasing the capability of man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems'. Our problem domain – the bio-functionality of the complex dynamic system that is the body, demands the development of multiple forms of new 'code' to enable a multi-perspective transdisciplinary approach to flourish.

Beginnings – clues from an arcane research history

Gordon Pask (1961) explored the notion of creating a chemical computer in his book *An Approach to Cybernetics*. He stated: 'Chemical computers arise from the possibility of "growing" an active evolutionary network by an Electrochemical process'. In a text entitled 'Physical Analogues to the Growth of a Concept' Pask states: 'My point of view about this question is as follows. It is reasonable to say that a machine does or does not "think", in so far as we can consider the working of the machine as in some way equivalent to a situation or an activity, (for example, riding a horse), which is familiar, and in which we ourselves are used to taking a part'. (Pask, 1959, pp. 765–794).

More recently research scientist Peter Cariani was inspired by Pask's approach and elucidated it in a paper – 'To Evolve An Ear: Epistemological Implications of Gordon Pask's Electrochemical Devices' (Cariani, 1993, http://homepage.mac.com/cariani/CarianiWebsite/PaskPaper.html). He states:

> Through the early and mid 1950's Pask experimented with electrochemical assemblages, passing current through various aqueous solutions of metallic salts (e.g. ferrous sulphate) in order to construct an analog control system. The system would be different from others in existence in that its design would not be completely well-defined: no explicit specification would be given for its parts. Pask was specifically looking for a machine that would create its own 'relevance criteria', one which would find the observables that it needed to perform a given task ... by evolving sensors to choose, independent of the designer, those aspects of its external environment to which it would react. Not only would particular input-output combinations be chosen but the categories of input and of output would be selected by the device itself.
>
> (Cariani, 1993, http://homepage.mac.com/cariani/CarianiWebsite/PaskPaper.html)

This notion of 'relevance criteria' is central to the potential of spawning new senses – new sensitivities to environment. We are not only developing an electrochemical computer, we also need to develop a related sensor network so the system can build up deep situated knowledge of environmental context. We must discuss the entire 'Body as Electrochemical Computer', not just the mind/brain, remembering that machinic and/or chemical senses also function to extend, amplify, and/or attenuate the potentials of human sensing and its relation to thought and experience. How can we create relevant 'analogue' senses, and observe the system for its 'responses' to the particular input that such senses might generate? We can also use mechanical and/or electronic forms of senses, if we are concomitantly articulating the appropriate transduction system to enable these senses to 'communicate' with the other functional parts of the system. It is interesting to contextualize such processes in terms of transdisciplinary research. In the Preface to Pask's *An Approach to Cybernetics* (1961) Warren S. McCulloch stated:

> This book is not for the engineer content with hardware, nor for the biologist uneasy outside his specialty; for it depicts that miscegenation of Art and Science which begets inanimate objects that behave like living systems. They regulate themselves and survive: They adapt and they compute: They invent. They co-operate and they compete. Naturally they evolve rapidly.
>
> (Pask 1961: p. 9)

Pask was an artist as well as a scientist, understanding the potentials of exploring a multi-perspective approach to adaptive systems. Interestingly, Pask would embody his scientific ideas in experimental works of art. McCulloch (in the introduction to Pask's text) went on to talk about biologically reverse engineering logic, a topic central to our notion of reverse engineering the bio-functionality of 'human' computers. We ask how is logic facilitated as a biological process? What are the entailments of how logic arises as part of thought? Could we, in the long run, trace the neuronal pathways and recursive loops that contribute to such human knowing?

In the 'Summary' of Pask's (1961) book*,* McCulloch states*:*

> A cybernetician adopts, so far as possible, an attitude which lays emphasis upon those characteristics of a physical assembly which are common to each discipline and 'abstracts' them into his 'system'. […] This is not a prudent methodology, for it runs the risk of seeming to be impertinent. It is justified in so far as it *does* lead to effective control procedures, efficient predictions, and acceptable unifying theories (and whilst this is true of *any* science, the sanctions are rightly enough weighted against a Jack of all trades). But the risk, on balance, is worthwhile, for the cybernetic approach *can* achieve generality and yield rigorous comments upon *organization*.
>
> (Pask 1961: 17)

Along with prediction we are opening out new research into the study of 'emergence'. Is thought an emergent property arising out of multiple operative aspects of the body's bio-functionality? If it is, we need to define mechanisms to fully unpack the body's complex entailment. In order to provide new insights into the workings of the body, one imagines the creation of new technologies of multiple varieties for measuring, mapping and articulating this complex arena of study.

One location where much research into bio-functionality as related to computation has taken place is the Biological Computing Laboratory (BCL). The BCL was the name of an independent division within the Department of Electrical Engineering at the University of Illinois, founded in 1957/58 by Heinz von Foerster, who at that time was Professor of Electrical Engineering in the department. In Albert Müller's text *A Brief History of the BCL, Heinz von Foerster and the Biological Computer Laboratory*, he discusses the Labs' historical position:

> I am equally motivated by the fact that the BCL has very seldom been mentioned in the literature on the history of cybernetics, systems theory, bionics (now the subject of renewed debate), parallel computing, neurophysiology, bio-logic, artificial intelligence, symbolic computing, or constructivism as an intellectual tradition – and it would be possible to list even more areas of science that are renowned today – despite the fact that workers at this institution, the BCL, figure importantly in the literature on each of these domains. Is this an oversight specifically on the part of the history of science (the forgetfulness of science itself being well known)?
>
> (Müller, 2000, http://bcl.ece.uiuc.edu/mueller/index.htm)

There is still much to be discussed in terms of our electrochemical computer paradigm, the 'insight engine' and their pre-history.

A combinatoric approach related to the Memory Theatre of Camillo

As we discuss the complexity of our subject we seek methods to create new insights related to memory and thought processes – to the entailment of the body as it relates to the production of thought and embodied experience. It is interesting here to point historically at the 'Memory Theatre' of Giulio Camillo (1480–1544). In the book *Theatregarden Beastarium*, Chris Dercon provides the following description:

> A spectator would sit at a central location inside a portable wooden structure which contained seven groupings of information, each accessible from seven different levels. The viewer would engage with an environment designed to reveal secrets about the structure of the universe, from the realm of the microcosmic to that of the macrocosmic. Viewers made choices from a central location, which enabled them to explore information housed in containers in close proximity to the participant. The room was organized in tiers which grouped information that dealt with questions of the universe, expanding upon innumerable aspects of creation.
>
> (Dercon 1990)

Given the complexity of our transdisciplinary subject, what would the contemporary approach be to such an architecture of information? It is clear that such an architecture is the physical/analogue precursor to the database. We seek to posit a set of relations between disciplines to help elucidate our approach to 'articulating' the body as 'electrochemical computer'. Yet we begin to see the importance of many differing approaches to the body. How might we construct a new technology, leveraging many different approaches and databases? Our multi-perspective approach includes approaches to many different experimental and discursive arenas: interfacelogy (Rössler's term, see Diebner and Druckrey's introduction to the symposium at the Sciences of the Interface Web site. See *Sciences of the Interface*, 15 Mar. 2001, http://193.197.168.165/symposium/.); physics and endophysics (Rössler 1998) (Seaman 2006); chemistry and biochemistry; cognitive science including psychology, mathematics, philosophy, neuroscience, linguistics, anthropology, computer science, neurophysiology, sociology and biology; genetics and protein communication research; robotics; humanities research; bio-ethics; nano-technological research; electrical engineering; research into aesthetics and creativity; visualization, hapticization and sonification; bioinformatics; information systems (to store and retrieve research data) including search paradigms, dynamic diagrams and mapping potentials; simulation research; media imaging; artificial life research; research into group tool authorship, distributed planning and discussion modalities; linguistic research; and a myriad of transdisciplinary historical references that have fed into the definition of each of the above domains. This seems like an absurdly open set of research foci, yet, we believe the key to much new research lies in the often hidden interstices existing between fields, and the designing of systems that help mine and organize relationality between current research fields, and in particular, in enabling human discussion to facilitate negotiation of relations between these diverse domains.

Along with Camillo's memory theatre, we also have the combinatoric potentials of Raymond Lull (1235–1316) which we can observe, suggestive of how we might explore knowledge production given the multiple fields that feed into our complex system analysis. We can imagine creating a series of concept 'triples' described above, by formulating relations through combinatorics derived from all of the pairs of disciplines listed above. Yet, we may need to focus on the generation of new 'triples' given the complexity of our subject and our multi-perspective, transdisciplinary approach.

Insight engine – the 'Thoughtbody Nexus'

A contemporary 'insight engine' (our tool of tools) would enable dynamic relationality to be explored. A large set of micro-process 'modules' or 'context-windows' would include a series of computational processes that would enable a chosen set of juxtapositions to be entertained locally and/or from distributed locations. In a contemporary 'theatre of thought' we could potentially explore recombinant semantic relationality enabling, through human/machine and human/human interaction; introspection, mapping, discussion, synthesis, juxtaposition, the examination of historical examples, conceptual analysis, the articulation of pattern relationality, structural relationships, differing modes of description, annotation of many forms, conceptual unpacking, the storage and retrieval of data sets, as well as enabling 'creative' discussion surrounding particular areas of study. One could also generate an ongoing set of new 'triples' to be enfolded as an operational part of the system via machinic processes.

In a related approach to the leveraging of multiple machine potentials, Licklider (1960) states:

> Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are, 1) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and 2) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs. In the anticipated symbiotic partnership, men (and women emphasises Seaman) will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking. Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much more effectively than man along can perform them.
>
> (Licklider 1960: p. 4)

The 'insight engine' would embody multiple forms of information, articulating differing methodologies and approaches to our multi-perspective bodily entailment. A long-term goal is to house the information such that one can 'chip away' at the causal underpinnings of bio-functionality – examining modes of articulation related to that which is at operation in the body enabling thought to arise.

Such a system might embody the following computational potentials:

- Storage and retrieval of information from multiple distributed sources.
- The searching of databases containing abstracts, papers and texts from many different disciplines derived through the use of 'triples' and/or other search methodologies.
- The facilitation of the ability to search – textual, media object, and/or entire multi-modal architectures of association that other researchers may have assembled.
- The operative employment of articulated relationalities between disciplines (to function as database filters) [new triples].
- The generation of linguistic tools (shared articulation schemes) including jargon translation systems and bridging languages, enabling discussion across disciplinary domains.
- The articulation of Boundry Objects.
- The housing of numerous forms of imaging including the ability to access dynamic models, emulations and simulations.
- The storage of maps of entailment.
- The storage of dynamic time-based diagrams.
- The ability to approach a process from multiple scales which could be brought into relational juxtaposition.
- The storage and retrieval of associated diagrams (as part of process) [including informal diagrams – e.g. discussion notes].
- The storage and active use of documentation of performative processes – video, and video 'mark up' potentials, VR and VR mark up languages, recorded discussion.
- The articulation of a time line of historical relevancies with the ability to search for time-specific data.
- The generation of a multi-scale virtual map of all relevant space – micromacro.
- The long term goal of articulating a map of the body and many of its intra-functionalities – micromacro. This might work toward articulating the entailment of neural connectivity and recursive loops.
- The development of new organizing principles – new cybernetic approaches across research domains (this would be enfolded with current approaches).
- The development of a poly-sensing environment enabling the connection between physical space and data space.
- Digital | Analogue cross referencing
- The ability to house relevant information related to evolution, deductive biology, genomics – living systems.
- The potential to provide multiple approaches to a given subject through texts – factual, fictional, historical and poetic.
- The potential to house systems of categorizations and meta-categorizations.
- The ability to explore and articulate ontology, genealogy, etymology and epistemology.

- The functionality to connect to multiple fields/disciplines/institutes and structures of collaboration across fields.
- The potential to use knowledge gleaned from the system to work toward the development of different technological instruments that extend human potential in an ongoing manner.
- The use of the system to help facilitate the articulation of new processes/ new approaches to science.

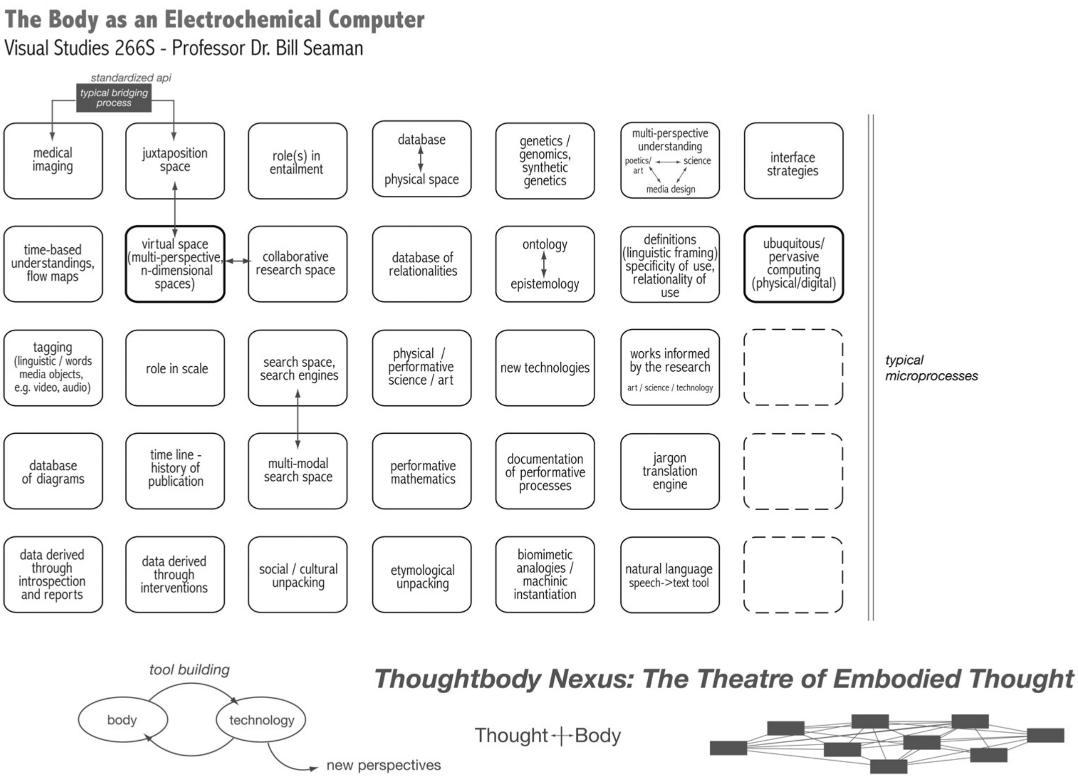

Figure 1: Insight engine – Modules for the 'Thoughtbody Nexus'. Concept by Bill Seaman, Image by Todd Berreth.

Real time generative relationalities

In particular, one seeks to articulate a series of relationalities from one micro-context to another that might be 'unearthed' by the system as it employs intelligent 'agents' to populate particular 'context-windows' of relevant micro-processes. Given a focused search in one domain, one could program the system to update across all of the included micro-processes, or be selective in an intelligent up-dating process. Collaborators could then call up and expand a window at will, enabling discussion and possible generation of insight. This would mean having the ability to 'hook' into distributed computational processes; each represented in a separate window, as well as 'connect together' a particular network of relevant context-windows either manually or in a generative encoded manner. Of course no individual has knowledge of all of the complex functionalities at operation in the body. Each individual research area is of vast complexity in and of itself.

Conceptual art, art and design

As an artist/researcher exploring meta-meaning relations, generative systems, virtual reality, and complex 'recombinant' media environments, I have long been interested in how interactive systems can enable media experiences to provide new insights into meaning production through interaction within both local and distributed computationally realized environments. The design of new computational systems that enable informed search across multiple research domains; dynamic juxtaposition of data; dynamic diagrammatic articulation; and the ability to network and discuss research questions through video conferencing (and video markup), as well as dynamic inspection of virtual spaces (and the ability to annotate such spaces); is in part informed by a series of aesthetic and design decisions that impact our ability to process information in the service of research and insight production.

Creativity

The study and unpacking of human creativity can help us design such systems. Bisociation processes (thinking on multiple planes simultaneously) as discussed by Arthur Koestler (1964) can be made operative in such computational environments, bringing the intelligent use of transdisciplinary foci to the fore.

Roy Ascott (1966) early on saw the potentials of 'behavioural' human/computer relations in terms of works of art. In his paper entitled 'Behaviourist Art and the Cybernetic Vision' Ascott presented the following concept:

> Behaviourist Art constitutes, as we have seen, a retroactive process of human involvement, in which the artefact functions as both matrix and catalyst. As matrix, it is the substance between two sets of behaviours; it neither exists for itself nor by itself. As a catalyst, it triggers changes in the spectator's total behaviour. Its structure must be adaptive implicitly or physically, to accommodate the spectator's responses, in order that the creative evolution of form and idea may take place. The basic principle is feedback […] There is no prior reason why the artefact should not be a self-organising system; an organism, as it were, which derives its initial programme or code from the artists creative activity and then evolves in specific artistic identity and function in response to the environment which it encounters.
>
> (Ascott 1966; pp. 247–264)

In this case, the project bridges art and science in a unique manner, contributing to ongoing research and a related poetics.

Linguistic frames

Along with this transdisciplinary research we must make sure our articulation and expansion of the definition of linguistic frames enables clear communication. Often differing research domains may use a particular term having a different meaning for each research field. We must be careful to develop bridging language and particular jargon translations that can function appropriately in differing publication contexts.

Complex systems theory

One approach to be enfolded in our multi-perspective study is that of complex systems theory. How will the study of complex dynamical systems provide a new means to help reveal the multi-scaled workings of the body? Can we develop new forms of time based dynamic diagram that might help us unpack such complex bio-functionailty? How will the creation of highly articulated simulations help us further our studies?

Enfolded topological spaces – historical relations

In looking for historical relations that inform the current research, we can connect concepts first articulated by Kurt Lewin (1936) in his text *Principles of Topological Psychology*. Here one seeks to 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 1936: p.54). 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' (Lewin 1936: p.54). This happens through 'dynamical communication', and this kind of topological set of relations fits well into the transdisciplinary functionality of the 'insight engine', enabling one to define a dynamic relationality between physical events, broad multi-perspective conceptual context building, and social/cultural framing. We will now shift from the long term approach of studying the entailments of the body to some initial approaches to the creation of an 'electrochemical computer', drawn from our preliminary studies.

An informed approach to the creation of an electrochemical computer

There are three different approaches to the creation of an electrochemical computer:

1. Biomimetic Digital Computation
2. Biomimetic Analogue Computation
3. Mixed Digital/Analogue Computation

Seaman and Otto Rössler have published a series of papers related to Neosentience (a new robotic and computational paradigm extending ideas from artificial intelligence) and in particular we have discussed the creation of an electrochemical computer. Recently Seaman began a related research project with Dr Timothy J. Senior, a Research Scholar at the Department of Information Science and Information Studies (ISIS) at Duke University. With his background in neuroscience, we are formalizing ideas for a biologically inspired electrochemical computer. Like Gordon Pask, we are also interested in the intermingling of scientific and artistic concerns.

Although still at an early conceptual stage, we envisage that our electrochemical computer will consist of modular components (akin to individual neurons), the flexible connectivity of which will permit them to be organized into different 'functional' populations. Our electrochemical computer will also exhibit a number of biologically inspired features, including:

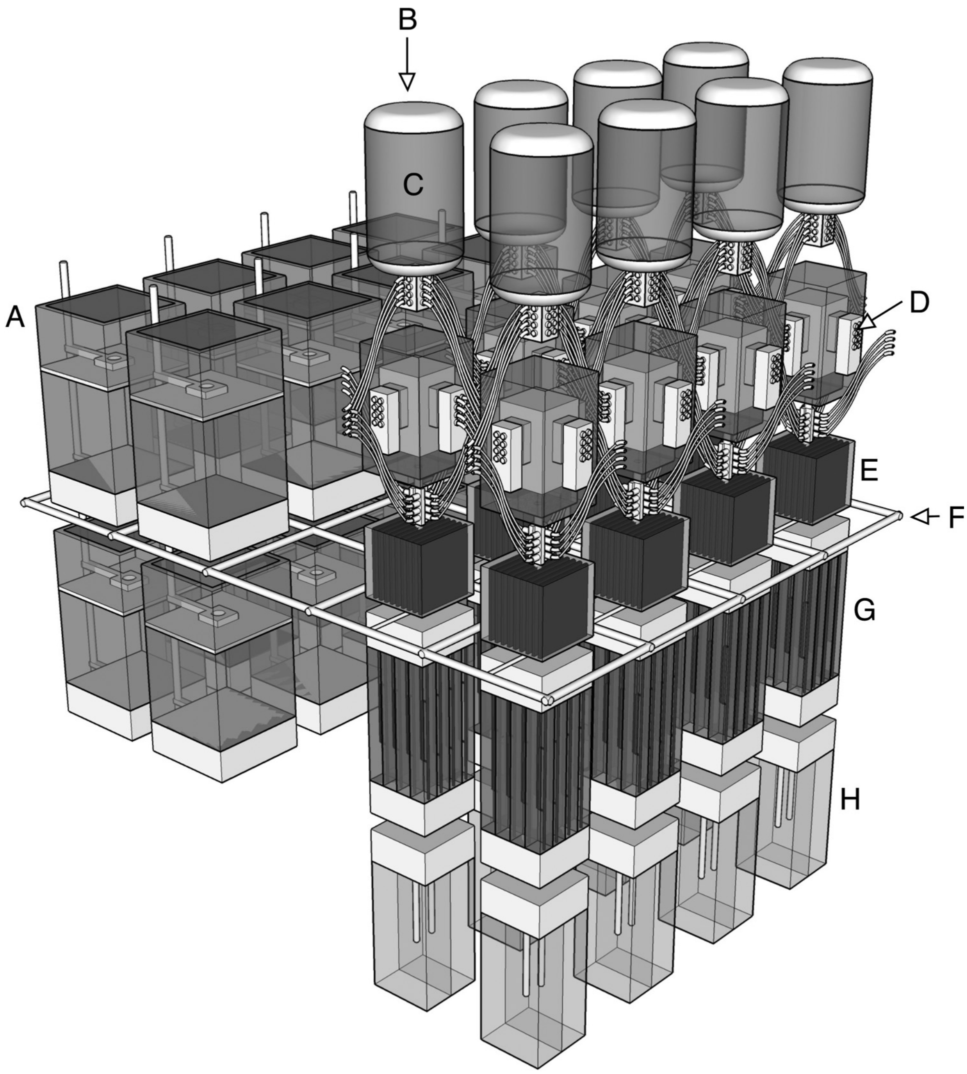

Figure 2: Figure showing one possible arrangement of modules within our initial electrochemical computer concept. Concept by Bill Seaman and Tim Senior. Image by Tim Senior. Figure showing one possible arrangement of modules within our initial electrochemical computer concept. A, Electrochemical oscillator unit; B, Module column; C, Neurotransmitter (NT) analogue; D, Site of control for NT analogue release; E, Processor – input integrator; F, Routes for direct external inputs; G, Electrochemical memory element; H, Electrochemical modulator unit used to drive either excitatory or inhibitory changes within modules from transduced external sources.

a chemical signalling system analogous to neurotransmitter systems; routes for externally derived sensory inputs of different origins to modify the behaviour of modules; memory elements, whose function will be inspired by biologically relevant learning rules; and finally, oscillation generators that modulate and synchronize activity within the electrochemical computer, akin to those contributing to many information processing functions within the mammalian brain. We are interested in the emergent behaviour exhibited by such a system when embedded within a 'sensed' environment. We are at the beginning stages of our research; a full discussion of the background and the working nature of the system will be presented in a forthcoming paper.

Neuromorphic systems

Along with the electrochemical approach another approach to our electrochemical computer might be via Neuromorphic systems (defined above) that make 'analogous' approaches embodied in silicon.

At the moment Seaman and Senior are focusing on the electrochemical approach. We are particularly interested in the qualities of complex multi-language analogue computation as a new research arena. The researcher Kwabena Boahen (Boahen, http://www.stanford.edu/group/brainsinsilicon/boahen.html), researching the Neuromorphic approach, states:

> Being a scientist at heart, I want to understand how cognition arises from neuronal properties. Being an engineer by training, I am using silicon integrated circuits to emulate the way neurons compute, linking the seemingly disparate fields of electronics and computer science with neurobiology and medicine.
> (Boahen, http://www.stanford.edu/group/brainsinsilicon/boahen.html)

We can imagine a mixed environment that employs both electrochemical processes as well as neuromorphic components. Our system might also include more common electronic computers to help control the system and possibly be employed to help 'train' it.

Summary

We are seeking to define a research paradigm that asks the following question from a series of differing disciplinary perspectives: What are all of the processes at operation in the body that enables human thought to arise? Additionally we are asking, how do embodied sensing processes and environmental relations contribute to thought production? This research seeks to 'chip away' at unpacking the deep bio-functionality at operation in humans that enables thought processes to arise. Much of this functionality is still a mystery due to the incredible complexity of the body. Yet, it is from this (and other) question domains that we discuss the 'Body as Electrochemical Computer'. We have chosen to develop a 'tool of tools', an 'insight engine' (the 'Thoughtbody Nexus') that might bring together many different micro-processes and computational contexts in the service of working incrementally toward solving the driving problems discussed above. We imagine there to be a recursive loop that extends the qualities and potentials of this insight engine as an ongoing pursuit – as a subset of the larger research goals.

This research seeks to illuminate the processes at operation in the body through a multi-perspective approach to knowledge production. It also seeks to understand how insights derived from the 'insight engine' might be abstracted in the creation of a new biomimetic computational paradigm. This research potentially provides us with new understandings about the complex bio-functionality of the body through the focused articulation of different levels and qualities of description (including poetic description), as well as through the production of relevant digital images, simulations, dynamic diagrams, and operational artifacts.

We imagine our system of recombinant informatics might be driven in multiple ways by differing interactants; sometimes exploring more poetic, aesthetic and/or humanities related perspectives as a generative system, along with scientific foci. Finally, to what extent can this life-long study, described above, inform the creation of related 'generative' works of art, as well as relevant conceptual and scientific study? Here, we can establish short term goal-sets that might arise out of knowledge gleaned from our ongoing research into the 'Body as Electrochemical Computer' through the use of the 'Thoughtbody Nexus', our 'insight engine'.

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