Toward The Creation of an Intelligent Situated Computer and Related Robotic System: An Intra-functional Network of Living Analogies

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Abstract

The potential is to generate an intelligent, situated computer-driven robotic system. Two different initial approaches are discussed: the creation of such a machine via the embodiment of a series of specific algorithms on a parallel computing platform working in conjunction with a specific situated machinic sensing environment and robot; and the development of a new paradigm for computing through the generation of an Electrochemical Computer functioning in conjunction with a robot and related sensing system. Rössler's seminal concepts including *A Relational Approach to Brain function*, and *An Artificial Cognitive-plus-motivational System* (among others*)* will be enfolded and form a top down "relational" analogical/biologic perspective informing both projects. We will also employ a bottom up inquiry exploring an approach for the development of an electro-chemical device, abstracting and applying Rossler's "relational" approach via an electrochemical articulation. This will include the development of a *Poly-sensing Environment* as it might be used to inform the machinic senses for both "entities"; and the notion of *Pattern Flows* of sense perturbations as applied to potential learning, language acquisition, embodied navigation and robotic behavior. The long term goal of this part of the project includes mapping and abstracting specific neural processes into an electrochemical/sensing/situated robotic environment.

Otto Rössler and Bill Seaman have been having an extensive conversation about the potential of generating an intelligent, situated computer/robotic system. The central contention is that an intelligent computational robotic system can be created. Two related but different initial approaches have been spawned through ongoing discussion. One involves the creation of such a machine via the embodiment of a series of approaches utilizing a parallel processing system — *The Benevolence Engine* (Rössler and Seaman)[1]. In particular, a project entitled *Intelligent Computerized Dolls as Companions in Old Age* was articulated in a paper delivered by Rössler earlier this year [Rössler, Hiwaki, Ratjen, Seaman, Locker, Lasker, and Aydin, 2005]. The other method seeks a long term approach

[1] Conversation between Rössler and Seaman

to posit a new paradigm for computing through the generation of an Electrochemical Computer and related robotic environment — *The Thoughtbody Environment*. [Seaman, 2004 and 2005] Both approaches are deeply informed by bio-mimetics and bio-abstraction.

1) A Relational Approach Through Analogy

In the paper *Adequate Locomotion Strategies For An Abstract Organism in An Abstract Environment – A Relational Approach to Brain Function,* Rössler articulates an initial relational, top down approach that functions as the first of a series of mechanisms to be enfolded in our system. The text describes developing "analogs" and a special "equivalence class" of bio-functionalities. The central feature of the "relational approach" is that it enables a stepwise narrowing of a very large model class as well as a means to articulate the "presence or absence of corresponding properties in the original system." [Rössler, 1973a]

It is clear that we cannot build a body from the ground up. We can only hope to reduce and approximate the salient processes that are at operation in the body that become enfolded and enable intelligence to arise. What are the essential processes that we must emulate in order to arrive at a neo-sentient machine? Certainly we must try to reduce the deep complexity of the body's functionality in a highly articulate manner. Perhaps the most difficult problem deals with not knowing which aspects of biological functionality contribute to sentience and which do not. Where historically one would isolate parts of the system to study it, it may be that only through a particular collection of intra-operative functionalities that neo-sentience might arise.

The systems we are abstracting from are vast and complex. Thus, in exploring mind / brain / body /environmental relationships, differing "relational approaches" must be carefully considered. Some associated approaches have been employed in other instances of contemporary research [Bar-Cohen and Breazeal, 2003]. Yet, we would suggest that as technologies advance, especially in relation to the observation of physical/biological processes on the "deepest levels", that ongoing *neo-relational* approaches need to be articulated and honed. It follows that we are sent back to new data from our bottom-up observations to better position the network of analogue assumptions that comprise the top down, relational approach. Thus, a bottom up | top down relational set of approaches is always potentially at play in the advancement of these particular branches of scientific inquiry.

Such "Locomotion Strategies" potentially address a series of important needs related to sentience. Rössler states the following in relation to his equation for a brain: that "the system performs compromises, shows anticipatory behavior, and posses self-teaching properties." It is also "adaptive." [Rössler, 1973a]

Although Rössler's system is described in his paper as a 2D, approach, it can be implemented in 3D space over time. This system is predicated on a "force field" motivational system. A "partially ordered series" of artificial motivational drives operated in parallel. One can picture a set of motivational sliders positioned via negative or positive reinforcement.

2) Enfolded Topological Spaces

We can potentially extend this approach by folding in concepts first articulated by Kurt Lewin in his text *Principles of Topological Psychology* from 1936 although one needs 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 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]

It will be the interlinking of these multiple topologies that will drive a potentially "intelligent" ongoing outcome to environmental interaction. We will return to the nature of this connectedness and enhanced interaction via language acquisition later in the paper. The question in particular is how can one map psychological goal state vectors to physical space vectors [drives to physical behavior]? One also asks what are the motivating variables that will inform the behavior of the system? This will be the subject of a subsequent paper.

The history of Rössler's research attests to his ability to abstract essential elements of functionality from many domains to find the solution to a particular problem set — analogical thinking. In the text, *Adequate Locomotion Strategies For An Abstract Organism in An Abstract Environment – A relational Approach to Brain Function,* Rössler defines a top-down relational approach to the control system of locomotion. He suggests that there is a deep "convergence" to biological reality via his system. He goes on to say that the "More realistic assumptions will lead to modified strategies each involving a specific type of 'learning'. The described first generation of *artificial brains* can be investigated further both by means of computer simulations and hardware realization (highly parallel type.)" [Rössler, 1973a]

This particular "brain equation" as Rössler calls it, has many potentials as articulated via the weighting of the parameters of positive and negative "values" fed into the system as an shifting/updated quality of each "motivational" parameter. This positive and negative weighting presents an ongoing means to attenuate specific "force field" potentials. Three basic assumptions are explored:

A) All environmental inputs are processed through a set of (continuously graded) delay channels, and the actual directional decisions are fed back in such a way that an immovable representation of the surrounding environment (and especially the actual force-field contained) is generated, along with a representation of the actual position of the moving dot inside this landscape.

B) The presence of rapidly decaying "virtual forces", corresponding to fictitious sources which appear in arbitrary directions for a short while (like will-o'-the –wisp's), determines the pursuit of short stretches of (from the local standpoint) "nonsense directions" inside the landscape.

C) Every time such a nonsense path happens to lead to a better point (processing a higher sum gradient than the former), the indeterminate path (formerly bridged by the rapidly decaying virtual gradient) is "filled up" with a longer lasting, "real" gradient in the landscape, -- All 3 assumptions together determine an iterative process which automatically converges, the iteration is automatically interrupted in favor of a relatively optimal direction.)[Rössler, 1973a]

Rössler saw great potential in this approach although it remains obscure in the current literature. He speaks about the potential importance of this concept: " It turns out that the strategies, obtained as 'simplest' solutions in dependence on the parameter 'average distances between sources' all can be interpreted as motivational systems. Rössler points out that there are "possible implications for experimental psychology, ethology, brain theory, and bionics." He also suggests that "the results of the present approach may have some interest for two branches of mathematics, namely artificial intelligence (including game theory) and logic theory". [Rössler, 1973a]

3) Motivational Systems and Electronic Approaches

Other early papers by Rössler inform the current approach. In his paper *An Artificial Cognitive-plus-motivational System,* Rössler provides the following: "…Optimizers are artificial motivational systems. They spontaneously seek an "optimum." That is something which is "best" or "most desirable." Yet, Rössler immediately articulates the difficulty with this assumption: "The essential problem hereby is, 'Best for Whom'? Is the optimum merely seen by the designer, or is there a higher instance present within the optimizing system itself (as a so-called "center of optimization")? He then provides the following definition: "Autonomous Optimizers are optimizers whose parameter space (the space within which they make their "moves") is identical with their physical environment, and whose utility functions are functions of their physical environment, computed by the optimizer." [Rössler, 1981]

Such systems may contain gradients of positive and negative feedback potentials that are weighted and manifest the ideals of the designer/programmer. They may also bring multiple optimizers together under one rubric. Rössler seeks to model aspects of cognition, in particular differing drives, and incorporate these. In the paper he provides an engineering problem which incorporates a directional evaluation simulation system and optimizer that functions via "panoramic sensors which simultaneously gather all of the required information." [Rössler, 1981] This is now expanded via multi-modal approaches to sensing. He later states, …to gather this information there has to be a "Buffer type memory into which the (successively acquired) information about the surrounding environment is being fed in such a way as to generate a simultaneous picture of panoramic type. Moreover, the elements of this picture must not have to be sampled anew whenever the changing system has changed its place, for then the required "orienting behavior" (turning around like a radar head) would use up a sizable portion of the time of the system. Rather, it will be cheaper to build-in a group-theoretic transformation that simply "updates" in a spatial sense) the previously gathered information— such that it is no longer obsolete even though the system has since changed its position in space. [Rössler, 1981]

Rössler compares this to a flight simulator. Where the flight simulator, updated spatially (based on a small number of coordinate points and instructions for the generation of connecting lines and planes [read virtual reality generator]) can be used as "an autonomous direction optimizer equipped with a universal flight simulator." He goes on to say, in terms of cognition the salient point is this: "The answer lies in inconspicuous observation: whenever one has such a built-in universal flight simulator available during normal locomotion[read VR generator, emphasis Seaman], then this flight simulator can (of course) also be used without overt locomotion…That is, an autonomous direction optimizer equipped with a universal flight simulator (in the above sense) has a much greater range of functional capabilities than an ordinary autonomous direction optimizer equipped with a panoramic transducer." [Rössler, 1981]

Thus, a "combined cognitive-motivational system" is posited. So we are step by step building up the potentialities of our system, by conjoining a network of functional analogies – in this case pointing at the functionality of the mind's eye as articulated through simulation potentials of the VR Generator. Interestingly enough, this analogue of the minds eye could be viewed by external observers!

Rössler suggests that in order to make the system optimally functional, additional requirements must be met. "First, that the locally computed 'utility horizons' (that is, the locally applying directional weights which as we saw, consist of several directionally distributed subfunctionals that have to be added) be stored along with the primary environmental information."… "That is internally generated information (subfunctionals) must be treated on essentially the same footing as genuine environmental information. [Rössler, 1981] He continues: "The simplest way to exploit the stored force field consists of the introduction of an internal coupling: if a certain direction when followed under simulation leads to a positive net effect …the local force field (field of directional weights and subweights) should be modifiable ("sustainable") accordingly….The most natural way (with the highest benefit /cost ratio) to do this has yet to be found." [Rössler, 1981]

Along with this he speaks about folding in the "rebuilding" of the "converging landscape" as a means to control the motor switch in the actual environment. He then suggests putting the control of the motor switch on "equal footing with the other weighting activities of the system." [Rössler, 1981]This deeply phenomenological approach draws again from a series of biological analogies. Rössler asks "Is there any reason to believe that an artificial combined cognitive and motivational system will also possess a phenomenology, and if so, will the later be related to our own subjective experience?" [Rössler, 1981]

4) An Artificial Cognitive Map System

In his paper entitled *An Artificial Cognitive Map System,* Rössler elaborates on the potential of his Cognitive map system. In particular he describes an "overlap buffer" that can be switched on and off. He states: "By memorizing past actions this makes it possible to carry out automatically a formerly simulated sequence of actions. This automatic execution has the asset that it permits, while going on, the simulation of something else (for example the next segment of motions). In this way two different sequences of anticipated views of the environment can be present on the screen simultaneously." [Rossler. 1981b]

Along with the overlap, this simulator can also do anticipative calculations and "look ahead." Rössler suggests that this corresponds to a "double checking" mode and suggests that this becomes a "recursive option." "In particular the number of levels which can be super-imposed on the screen using this option is in principle unlimited." [Rossler. 1981b] Thus, multiple buffers can be drawn on. He here suggests that one can substitute his "autonomous direction optimizer" described above, for the "screen and control knob" enabling the shift between current environment and the VR of a simulated environment.

5) Pattern Acquisition / Language Acquisition

Seaman believes these buffer levels could also be used for pattern acquisition, learning, pattern production, and abstraction as well as generative recombinance of patterns, or in other words — language acquisition and language production as a long term "learning" / productive goal. [Seaman, 2005]

Rössler goes on to talk about how the system might be augmented in differing ways. Other learning systems might be incorporated into this system. Moving toward a salient "biological" model, Rössler suggests how this might be accomplished: "A model of Albus (1979)[2], related to one of Marr (1969)[3] is also compatible with the present approach. This model is hierarchical, stressing the importance of motor learning at several levels. All the lower-level units of Albus' model can be incorporated in the present model (in place of its 'prewired' connections. Conversely, the present model is appropriate to be incorporated into Albus' model on the highest hierarchal level." [Rossler. 1981b] Thus, such a system would need to be trained over time in a situated manner, to obtain higher-order functionality.

6) Benvolence Theory

Rössler, in conversation with Seaman, has spoken about the potential of generating an intelligent computer as arriving in part, through a mutually reinforcing benevolence feedback loop + mirror knowledge, functioning in conjunction with the previously articulated set of biologically abstracted force field variables, different qualities of memory buffers and sensing systems. Rössler is developing a new paper to articulate the benevolence aspect of the approach. We will now shift gears from more common computers to the potential of Electrochemical computers.

7) Toward an Electrochemical Computer – The ThoughtbodyEnvironment

One forcus of this project has been geared toward more traditional computers. Yet, as humans we are ThoughtbodyEnvironments nested within the greater environment—complex electrochemical computers of a sort that have as yet not been duplicated artificially. Gordon Pask was seminal in terms of his approach to the notion of growing a computer. "Chemical computers arise from the possibility of 'growing' an active evolutionary network by an electro-chemical process."[Pask, 1961] How could we grow a computer that incorporates the salient aspects of the human computer? What are the key components to such a network — a network that in time may enable neo-sentience to arise? What kinds of processes can we set in motion to emulate human functionality? How can we work toward enabling a network of these processes to become intra-functional? If we understand embodiment as essential to meaning production then how can we manifest this network to include embodied experiences? On the difficult path leading to the production of an electrochemical computer, can we devise strategies to employ in more traditional computing environments that are informed by our electrochemical researches. Alternately, can initial ideas related to the construction of intelligent computers (our analogues articulated earlier in this paper) inform our research into electrochemical computing?

8) Chemical Circuits with Non-trivial, i. e. Exotic, Dynamical Behavior

Although the system described initially in this paper is predicated on a more traditional computing environment, could we devise an analogous chemical and/or electrochemical network that might generate similar outcomes given the appropriate level of programming and situated training? How can we go about developing systems that become operative via an electrochemical substrate that functions analogously to our own embodied thought and language production processes? Interestingly, Rössler published a paper in the same book as the above entitled: *A Synthetic Approach to Exotic Kinetics*. Here Rössler states: As an aid for intuition, three sources for the generation of

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[2] Albus, J. 1979, A Model of the Brain for Robot control, part 4, mechanisms of Choice, Byte 4(9), 130-148

[3] Marr, D., 1969, A Theory of the Cerebellar Cortex. J. Psysiol. 202, 437-470

new chemical circuits with non-trivial, i.e. exotic, dynamical behavior are offered:

(a) the analogy to electronic circuits ;
(b) the analogy of neural elements
(c) the analogy to already existing chemical circuits, invented by mathematical biophysicists."[Rössler, 1973c],

Suffice it to say, it appears that the above system of motivation, optimization, cognitive mapping, learning, recombinant patterning etc. could be approached via one or more of his "exotic" methodologies. At the time of writing (1973) Rössler's theories were purely theoretical. At the conclusion of the paper he provides the following summary: "On the basis of non-physical analogy between homogeneous reaction systems and electronic systems (concentrations corresponding to voltage), spatially homogeneous chemical analogues to a number of well known electronic circuits can be devised in abstracto (amplifier, rectifier, RC oscillator, Eccles-Jordan trigger, multivibrator, time-based generator, monoflop, single-sweep time based generator), some of which are identical to already existing abstract reaction systems. [Rössler, 1973c].

To what extent can such knowledge inform a new approach to emulating embodied neuronal functionality? In conversation with Rössler, we initially discussed the potential of using this form of *Chemically Well Stirred Reaction*. Only a few variables can be worked on simultaneously with this kind of system. Yet one could imagine a room with many of these reactions going on side by side, forming an elaborate connected neural correlate.

9) An "Exotic" Electrochemical Approach

The potential to make an electrochemical neural-analogical mechanism is also articulated in the paper. Rössler states: "Cowan (1972)[4] postulated a 'neural field theory', being based on a Bonhoeffer-type partial differential equations (in the present terminology), which also allows for catastrophical [any perturbation which takes the system across such boundaries will switch the system from one dynamical regime to another… are called 'Catastrophies',[5] emphasis Seaman] shifts between different regimens of qualitative behavior. An analogous simulation result ("hysterisis behavior") has been obtained in discrete neural nets by Anninos [Anninos ,1972][6]. Thus a topological theory of the brain" Zeeman, (1965)[7] begins to emerge in operational and even chemical terms."[8] [Rössler, 1973c]

This is a particular electrochemical reaction which has been known for quite some time. An iron wire model is placed into a particular acid solution. The wire becomes coated with a layer of oxide which protects it. If you "strike it with a needle a wound in the oxide travels along the wire"[9]… K. F. Bonhoeffer wrote a paper entitled *Activation of Passive Iron as a Model for the Excitiation of a Nerve*, presented for publishing in 1947.[10] In it he outlines the characteristics of this living electrochemical "analogy" to neural processes. He states: "It is indeed most astonishing that iron wire and nerve, which from the chemical point of view differ so enormously, function in such a similar way. It does not seem credible that the various functional properties in which the two systems resemble each other could be independent and accidental similarities. There is here a most interesting problem from the point of view of reaction kinetics. The existence of a threshold of activation, of a refractory state, of a transmission of activation, of a tendency to give rhythmic reactions, and a suggestion that even the so called accommodation effects are not missing in the model, indicated that all these properties, so uncommon in ordinary chemistry, are in some way related to each other."[Bonhoeffer, 1947] How could we build a system that transfers new analogies abstracting currently known neural properties — micro tubules, volume transmission, bio-luminescence, etc…?

This process could be expanded and built upon to define an electrochemical system to emulate neural activity. The problem with this solution is physicality. There is no particular reason that would keep the above motivational mechanisms etc. from being realized in such an environment. Of course "programming" the system poses some problems (the system would need to be "brought up"), as does the physicality of its potential size, and the care and up-keep of its distributed components. So first we would emulate this analogue parallel processing system, in a standard (as powerful as possible) computer. As a physical neural net analogue, we would also seek to emulate as many physical qualities as possible that are inherent to mind/brain/body/environment relations. Massive today, one can imagine a bio-nano analogue that would be much smaller in scale — closer to our neural physiology. Rössler suggests that this is 40 years out. I imagine a huge shift brought about through nano research as well as genome related manufacturing as coming about sooner (in the next 10-15 years).

What I am imagining is the analogue of a neuron farm as articulated in some electrochemical environment. This huge room would enable the system to be regulated. The room could be connected at a distance to a robot that it was communicating with at the speed of light, both receiving pattern flows of sensed perturbations, as well as sending

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[4] Cowan, J. , 1972, *Stocastic Models of Neuroelectric Activity*. In **Towards a Theoretical Biology**, 4, C.H. Waddington, ed., University Press, Edinburg, pp. 169-187
[5] ibid
[6] Anninos, P.A.: 1972, *Mathematical Model of Memory Trace and Forgetfulness*, Kybernetik 10, 165-170
[7] Zeeman, E. C.: Topology of the Brain (Mathematics and computer Science in Biology and medicine), Medical Research council, 1965
[8] Rössler, Otto, 1973, *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. Güttinger, and M. Dal Cin., Springer-Verlag, Berlin, Heidelberg, new York, p. 577-578
[9] Conversation with Rössler
[10] Bonhoeffer, K. F. 1947, *Activation of Passive Iron as a Model for the Excitiation of a Nerve*, From ther Physical Chemistry Institute of the University, Berlin, http://scholar.google.com/scholar?hl=en&lr=&client=safari&rls=en&sa=X&oi=scholart&q=iron+wire+model+oxide+Bonhoeffer

robotic affector commands. It could also be tied directly to more traditional computers.

Michael Conrad and others have gone on to articulate an entire field of chemical computing related to DNA. Certainly similar modeling systems could be used to simulate such an environment.[11] Although we here are suggesting one particular approach to the creation of an electrochemical computer, we are still researching the potentials of differing approaches to the construction of a deeply biologically inspired neural emulation system, functioning in relation to a sensing body that is situated in the environment.

10) Potentials of Poly-sensing Environments

A poly-sensing environment (a network of inter-communicating bundled sensors with specific object-based authorship potentials) could potentially function as the senses for the two systems. [Seaman, Verbauwhede, Hansen, 2004] This is an environment that explores patterns of multi-modal perturbations as a phenomological situated approach to environment. I will further articulate the potentials of poly-sensing environments in a subsequent paper.

Summary

In terms of the generation of an intelligent situated computer we need to ask what kind of computer are we? We have laid out the initial plans for a "relational" approach from a salient selection of analogue processes that arise out of defining a specific "equivalence class of systems" related to intelligent functioning. These are "all defined according to their sharing a single aspect (e.g. a functional performance) with the original system." [Rössler, 1973a] We have in particular drawn from the seminal texts of Rössler, as well as new texts by Seaman, and enfolded these concepts to inform the potential generation of an intelligent situated computer and related robotic system, created via the employment of an intra-functional network of living analogies. Such a system could be explored either through electrochemical processes and/or through more standard computational processes.

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[11] See http://www.kli.ac.at/theorylab/AuthPage/C/ConradM.html for numerous related papers.