Anticipation | Computational Creativity

Professor Dr. Bill Seaman

Department of Art, Art History & Visual Studies

Media Arts and Sciences

Duke University

Abstract

The paper will outline the role of anticipatory systems as part of a set of computationally driven creative processes. Here the goal is to both use the computer as a tool functioning in the service of human creative processes e.g. authoring a system to help compose generative music, as well as to begin to explore "learning" and the abstraction of creative processes in terms of autonomous computational creativity. Anticipation is here undertaken in a mindfully-aware manner, as drawn from the deep study, understanding and articulation of human creativity. Thus, this research seeks to define the driving problems in authoring autonomous generative computational systems through the pragmatic application of biomimetics and bioabstraction, drawing in part on the study of human anticipatory systems that play an active role in creative processes.

Keywords: Computation, Creativity, Computational Creativity, Machinic Creativity, Re-embodied Intelligence

Introduction - Anticipatory Systems

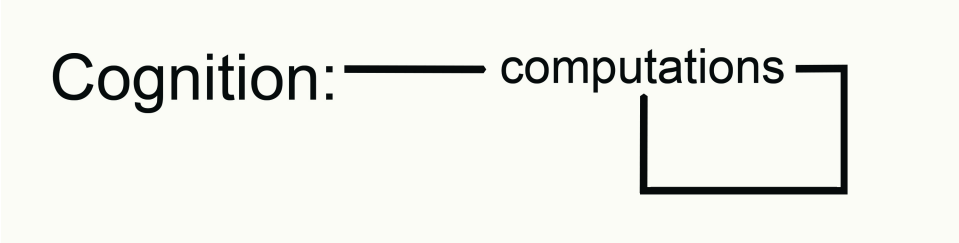
Robert Rosen wrote one of the seminal texts on anticipation called *Anticipatory Systems*. He *anticipated* much of what this series of conferences seek to examine:

> I have organized [this volume] around the concept of anticipation, which is fundamental in its own right, and which connects naturally to a cluster of other concepts lying at the heart of natural science and of mathematics. Strictly speaking, an anticipatory system is one in which present change of state depends upon future circumstances, rather than merely on the present or past. As such, anticipation has routinely been excluded from any kind of systematic study, on the grounds that it violates the causal foundation on which all of theoretical science must rest, and on the grounds that it introduces a telic element which is scientifically unacceptable. Nevertheless, biology is replete with situations in which organisms can generate and maintain internal predictive models of themselves and their environments, and utilize the predictions of these models about the future for purpose of control in the present. Many of the unique properties of organisms can really be understood only if these internal models are taken into account. Thus, the concept of a system with an internal predictive model seemed to offer a way to study anticipatory systems in a scientifically rigorous way. [1]

As we begin to explore the authorship of organism-like machines, though biomimetics and bioabstraction, such a book becomes central in outlining a series of specific perspectives that illuminate the concept of anticipation in terms of differing kinds of systems. The creation of computational generative art systems

requires the writing of specific code informed by various biological and in particular conceptual processes. Yet, the fact that we are seeking to generate emergent systems points to a strange kind of predictive model, a model that predicts something that is intentionally not fully known— that is emergent in nature. Thus it predicts a kind of behavior or outcome of surprise and/or novelty.

When we undertake a decision making process we undertake a "mental simulation" related to potential future outcomes. In "Perception of the Future and the Future of Perception" (first given as an address in 1971 but published much later in *Observing Systems*)[2], von Foerster was also interested in thinking about 'thinking about' the future. As we think about a relationality between the human and the computer, in the same volume von Foerster also expressed the idea that



[3]

Rosen in *Anticipatory Systems* states: "Intuitively, we would expect the concept of a system to involve some kind of inter-relation between the percepts it generates, and which then become identified with corresponding relationships between external qualities which generated them." [4] In Generative works of art one abstracts and computationally re-embodies qualities and relations that can potentially generate percepts in a focused manner. Rosen goes on to say "Briefly, we believe that one of the primary functions of the mind is precisely to organize percepts. That is, the mind is not merely a passive receiver of perpetual images, but rather takes an active role in processing them and ultimately in responding to them through effector mechanisms." [5] This is where we build up a sense of aesthetics, and of the potentials for the authorship of generative processes. Here computer code functions as the "anticipated" organizing mechanism, and/or becomes operative as part of an "anticipated" interactive human/computer system. Rosen discusses "Encodings Between natural and Formal Systems" --- "In authoring generative systems we seek to encode natural systems into formal ones in a way which is consistent…"[6] This is the case with generative systems, we seek to author a system that would function in a manner appropriate to that which is being modeled.

Rosen compares a natural system to a formal one:

> A natural system is essentially a bundle of linked qualities, or observables, coded or named by specific percepts which they generate, and by the relations which the mind creates to organize them. As such a natural system is always incompletely known; we continually learn about such a system, for instance by watching its effect on other systems with which it interacts, and attempting to include the observables rendered perceptible thereby into the scheme of linkages established previously. A formal system, on the other hand, is entirely a creation of the mind, possessing no properties beyond those which enter into its definition and their implications." [7]

Yet, we seek in a sense to transcend Rosen's statement through the operative nature of our formal computational systems— we seek emergent phenomena that arises through combinatorics and/or artificial life processes, as well as through complex loops of processes that make percepts operative and newly relational over time. Perhaps this falls under the notion of a formal system's "implications," or perhaps we are working on systems that are different to the ones described above. We seek to make a system that can generate aspects of "novelty" out of formal elements and processes— to surprise…

1.0 Computational Creativity

Margaret Boden in her book *Creativity and Art - Three Roads to Surprise* defines creativity as "the ability to come up with ideas or artifacts that are new, surprising, and valuable." There are many questions related to whether computers can be creative in and of themselves. Margaret Boden in *Creativity and Art* states, in relation to the difficult questions of computational "consciousness, intentionality, and the role of 'brain-stuff' and/or embodiment":

> Since the notoriously controversial problems remain unsolved, I nowhere claim that computers are "really" creative. If and when I mention creativity in computers I am really asking what aesthetically interesting results can computers, generate and how? And just what might lead someone to suggest that a particular computer system is creative or that its functioning is somehow similar to creativity in human beings. [8]

Computational Creativity has been defined by the *The Association for Computational Creativity* as "the study and simulation, by computational means, of behavior, natural and artificial, which would, if observed in humans, be deemed creative." They have held four conferences to date. [9] Seaman, early on discussed the notion of *Re-embodied Intelligence* [10]. *Re-embodied intelligence* can be defined as the translation of media elements and/or processes into a symbolic language enabling those elements and processes to become part of an operative computer-mediated system. The ability to "translate" the aesthetic conceptions of an "author" into a form that is operative within a technological environment is fundamental to the creation of interactive (and other forms emphasis the author) artworks. We will consider "intelligence" as referring to activities we have in the past considered intelligent, like "playing chess say or recognizing visual images." [11] In the creation of artworks the artist employs modes of thinking that might be considered illogical, nonsensical, intuitive, metaphorical, non-linear etc. The intelligence embodied in an individual's art practice, functions in the service of their poetics. This process of re-embodiment is entirely anticipatory. Initially one must become "mindfully aware" of the aesthetic processes. Varela, Thompson and Rosch in *The Embodied Mind* speaking about mindfulness/awareness suggest:

> Its purpose is to become mindful, to experience what one's mind is doing as it does it, to be present with one's mind. What relevance does this have to cognitive science? We believe that if cognitive science is to include human experience, it must have some method of exploring and knowing what human experience is. [12]

So for the purposes of this paper, Seaman will take a Second Order Cybernetic approach, placing himself as an artist inside of the system, exploring a series of human/computer relations and potentials through introspection and a history of education in the arts informing this position. Thus, this study becomes part of a social and cultural milieu as well as ongoing experience gained through over 30 years of artistic practice. [13] In the long run, learning systems may also become enculturated. Seaman posits that there is an interesting change going on where simulation (discussed above in the definition of Computational Creativity) and actuality, pivot and shift. At a certain point one is not simulating an image --- one is generating a computer-based image that is of-itself. As we move toward the exploration of intelligent systems, especially in terms of robotics and autonomous learning systems, we can anticipate systems with real-world functionality that are no longer just simulations. This conflates the definition of natural and formal systems as discussed by Rosen above, especially when the system is emergent in nature.

It must be noted that Ada Lovelace at the very beginning of computer programming in 1842, in her *Notes to the Analytical Engine* discussed the potentials of exploring different kinds of relational elements. In her Notes by The Translator written to clarify the textual work entitled Sketch Of the Analytical Engine Invented by Charles Babbage by L. F. Menabrea, Lovelace made some very relevant remarks:

> The Analytical Engine is an embodying of the science of operations,
> constructed with particular reference to abstract number as the subject of those operations... Again, it [The Analytical Engine, emphasis Seaman] might act upon other things beside number were objects found whose mutual fundamental relations could be expressed by those of the abstract

> science of operations and which should be also susceptible of adaptions to the action of the operating notation and mechanism of the engine. Supposing for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expressions and adaptions, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent... It may be desirable to explain, that by the word operation, we mean any process which alters the relation of two or more things, be this relation of what kind it may. This is the most general definition and would include all subjects in the universe. [14]

As a programmer/artist, in order to author such a system, each operative relational element can potentially be "anticipated" in the authorship of coding. Lovelace articulates the 'universal' nature of this approach pointing to the computer as an open system. Yet, the relationality of media-elements and processes brought about through exploration within such systems can be emergent in nature. In specific situations, where the system exhibits a particular level of complexity, paradoxically one can anticipate aspects of aesthetic emergence as an arising state of the system.

The creation of generative artworks can take a series of different forms. Seaman and John Supko are co-leaders of the *The Emergence Lab* in Duke University's new program in Media Arts + Sciences. Last spring they taught a class in *Generative Arts* exploring approaches to image, sound/music and text. Seaman has a long history of creating artworks that are emergent in nature. Anticipatory systems are used in a number of different ways in the creation of these works. In terms of anticipation, every different potential artistic variable as well as the processes that might be called up to operate on those variables, can potentially be considered (anticipated) in the authorship of generative work. A series of variables can be discussed from the perspective of still and time–based image production, generative music/sound, and generative text.

1.1 Some Anticipatory Approaches to Image

In the creation of generative works of art, be they interactive and/or a stand alone generative systems, anticipatory approaches play a central role. In Seaman's practice chance processes are used within 'ranges' of chosen media variables, drawing from media-element databases. [15] [16] Here one can potentially "load the dice" in terms of the heightening the probability of calling in particular media-elements by loading the system with media that already has a set of aesthetic qualities — an overarching sense of color, composition, subject matter, and overall aesthetic etc. This might include the loading of a particular database of still images, digital video works, 3d images, or time-based animations in 2D or 3D. Each media element becomes an anticipated variable module. Along with these media elements, a series of time-based media processes can also be considered. This might include how the media-elements enter the time-based image (e.g. does it dissolve, slide, or cut in – there are many different kinds of transitions that can be explored). The way time unfolds in the work is also anticipated — the speed of playback – e/g slow motion, extremely fast motion etc. Additionally the nature of repetition of the image; the scale of the image; the angular position of the image (flat texture map) in 3d space e.g. the image might be skew to the frame or intentionally presented in an odd/shifting perspective over time. The level of the transparency of the images can also be explored. In terms of the final authorship of the code, the work can be tested in an iterative manner and the code can be adjusted and altered to better reflect the aesthetics of the artist/author/programmer. This "adjustment" alters the probability of the occurrence of particular events. This programming enables a form of controlled anticipation, yet it is also paradoxically open given the chance elements and processes involved in the programming, and the combinatoric nature of the layered composite time-based image that is generated. Although the database is finite, the layering and combinatorics associated with the work, as well as the application of different media processes in time, render it emergent in nature.

Along with the generation of the image, related music and sonic material can be generated via a number of computational means. I speak below about some of the sonic parameters that can be explored in an anticipatory manner. In terms of image / sound relations Seaman seeks to create a metaphorical resonance.

Here aesthetic coherence that juxtaposes visual attributes with sonic qualities is explored in terms of image/sound pacing, rhythm and mood. In terms of this kind of work of art, one lays out a set of qualities that pave the way for the "reading" of the work in an abstract manner that continues to unfold over time. The viewing of the work over an extended period of time, enables the viewer to anticipate how the work will continue to unfold. In this sense the work [and many other experimental works] defines (and anticipates) its own viewing expectations as part of its own structural strategy.

1.2 Anticipatory Approaches to Music/Sound

In terms of music / sound, every different kind of sonic aesthetic variable can be "anticipated" in code authorship. John Supko calls this Parameterization [17]. We return to the notion of re-embodied intelligence discussed above. In this case if one was to compose a piece of music, what kinds of relations and qualities would one find of interest to include. One approach is to take a finished work and carefully analyze it in terms of all of its aesthetic qualities. Then one seeks to abstract each of these qualities into a system that enables and heightens the probability of certain events to arise. This is especially true if one is interested in chance processes being incorporated in the work. One can also compose a work with very specific branching structures but these are more formal in nature. Sonic variables that Seaman has explored in differing works include rhythm, pitch, sonic dynamics, vocal intonation, form, timbre, duration, meter, sequence (repeated pattern), tonality, dissonance / consonance relation, harmony, texture, orchestration, register, sounding on the beat / off of the beat, the layering of noise elements, and elements of chance.

One approach Seaman has returned to in a series of different audio pieces has been to work with loops and combinatorics. He uses Ableton Live (and pro-tools in the past) as a program to build the loops in. Initially generative works were made with tape loops in the early 80's. In this case Seaman builds these loops exploring the sonic variables listed above. Ableton also has a series of effects built into the program so the sound can be highly crafted. Thus, each loop is computationally 'composed'. This functions as a "loading of the dice", similar to the notions discussed above in relation to imagery, where the sonic aesthetics are crafted with great care. This approach to the system anticipates that each loop will be played with another from the system-set at some point in time. These loops are created to repeat in exactly the same place with the same duration. One can also intentionally explore loops of differing lengths that explore permutations of changes over time. Seaman has taken this approach in other works. As the same-duration loops are added in one at a time, Seaman listens to how these work together in differing combinations, both as pairs and as multiples intermingling. Each addition of a new loop means much testing in terms of turning them on and off. Yet here Seaman comes up against the vast number of permutations that one arrives at as more and more loops are added to the system. Sometimes up to 50 loops are explored in one system. At a certain point, not "all" permutations are tested but a kind of "averaging" where a subset are tested together. It is anticipated that if the loop works with the subset of multiple other loops musically, that it will have a strong probability of sonically "working" with the entire system in terms of the aesthetic parameters that are being modeled. As more and more loops are layered together there is also an emergent sonic quality that arises.

Seaman has collaborated with Daniel Howe in creating an engine to play back these loop sets. The engine has some interesting parameters that the user of the system can alter: these include the number of loops that will be called in at one time and the number of loops that will change/stay the same after a specific number of repetitions. One can also play the system by turning loops on and off during playback. Seaman performed his work "A China of Many Senses" at Duke University, singing and speaking live on top of specific loops.

Seaman is now collaborating with John Supko on a work called s_traits. In this work Max MSP has been used as a "controlling" or "anticipation" engine, where after our discussions John has authored many different "patches" seeking to explore a alternate approach to the sonic variables. Discussion of this work will be the source of a different paper. One concept under discussion is the notion of modeling "listening" as a way to trigger new events. When the system "hears" a particular quality it is listening for, it may add in material from a particular database. This approach also moves away from locking in loops, and explores non-regular juxtapositions informed more from experimental and contemporary classical music. Supko

authored a series of “remix” engines as a way to explore permutations quickly via human/computer interaction. The outcome of use of these systems was used to build modules that can be called in from a database. Here one can also use meta-tags in terms of facilitating “anticipation” of particular sonic variables or qualities – drones, rhythms, specific pitches etc. Where the audio system “listens” and responds based on particular parameters that have be pre-authored. Audio files from a folder with particular meta-tag may also be called into the ongoing composition. Here a form of code-based synthetic perception is used to inform analysis and anticipated feedback in terms of choosing new computational elements and processes to unfold over time.

1.3 Interactivity

Seaman has also explored interactive systems that enable a listener to call in and or position differing audio loops in virtual space. This was quite a unique approach in that all of the variables are anticipated, but here the participant makes a mix through their positioning and subsequent navigation of the generative space. Again, there are probabilities at work. In this case the participant can also “anticipate” potential navigation based on the sonic choices that they make from a database to be positioned in the virtual world. One can also “perform” the interactions as a compositional methodology.

1.4 Textual Anticipation

Although there are many systems that generate text, Seaman has chosen to explore a method of exploring Re-embodied intelligence for a number of his works, starting with his media/text generator - *The Exquisite Mechanism of Shivers* [18]. To first derive the variables for his generative text Seaman wrote a singular complex sentence. He divided this into 10 segments. He then carefully, one at a time began to write a series of substitutions. This enabled him to craft the vocabulary and also anticipate shifts in the meaning of the text. Like the creation of the generative music variables, Seaman could begin to build up the sentences seeing how the substitution would work in relation to the differing contexts that the alternative linguistic variables would bring about. This also meant Seaman could keep to a particular grammar and syntax in a patterned manner. In particular, Seaman anticipated the generation of multiple meanings/readings through polysemy in the choice of words, often employing homonyms. Yet, like the music, as the system became larger the combinatorics became astronomical in number. Seaman again would explore a series of substitutions in terms of how they worked poetically, yet the system would later continue without testing every substitution. Here Seaman anticipated the generation of emergent texts, yet loaded the dice by inserting very specific vocabulary.

1.4.1 Markov Chains and N-Grams

Many experimental media authors explore Markov Chains for generative textual authorship. Daniel Shiffman provides a definition:

> A Markov Chain can be described as a sequence of random "states" where each new state is conditional only on the previous state. An example of a Markov Chain is monopoly. The "next" state of the monopoly board depends on the current state and the roll of the dice. It doesn't matter how we got to that current state, only what it is at the moment. A game like blackjack, for example, is different in that the deal of the cards is dependent on the history of many previous deals (assuming a single-deck not continuously shuffled.) We can use a markov chain to generate text where each new word or character is dependent on the previous word (or character) or sequence of words (or characters). This is known as an N-gram model. An N-gram model for language predicts a word (or character) W[i] based on the previous sequence W[i-2] W[i-1], etc. Given the phrase "I have to" we might say the next word is 50% likely to be "go", 30% likely to be "run" and 20% likely to be "pee." We can construct these word sequence probabilities based on a large corpus of source texts.[19]

Thus, again we can "load the dice" by supplying a specific source text or Corpus and exploit the "predictive" nature of such a system. This again explores probabilities, so the anticipatory nature is not fixed but is "heightened" so to speak.

1.4.2 RiTa Toolkit

Daniel Howe has created a toolkit for the exploration of Generative texts called RiTA:

> RiTa is designed to be an easy-to-use toolkit for experiments in natural language and generative literature. RiTa is implemented in Java and JavaScript with a single API and optionally integrates with Processing. It is free/libre and open-source via a GPL license.
> Some of the features of RiTa include:
>
> • Text-generation via Context-Free Grammars and Markov-chains
> • Taggers for Syllables, Phonemes, Stress, Part-of-Speech, etc.
> • Modules for tokenization, verb conjugation, pluralization, and stemming
> • A user-customizable lexicon with a letter-to-sound phoneme generation
> • A standard set of 'easing' effects for animation & textual behaviors
> • Integration with Processing, ProcessingJS, and NodeJS
> • Runs in or outside the browser, with or without Processing (also in Android)
> • Integrates with (locally-installed) WordNet dictionary[20]

Here Howe has brought many textual variables into a "toolkit" space that enables authors to experiment and find new approaches to generative text. The toolkit anticipates many different kinds of explorations yet the system is open in terms of how programmers/authors might choose to explore it.

2.0 Machinic Autonomy – The future in generative systems.

We can anticipate a future where computers take on more and more autonomy in the creation of works of art. As we begin to author learning systems of deep complexity, one can anticipate what Ray Kurzweil discusses in his book – *The Singularity is Near* [21] - fully autonomous thinking/learning machines. Of course there is a great debate surrounding this possibility, as well as fear of highly intelligent machines. Seaman and Rössler in their book – *Neosentience – The Benevolence Engine*[22] discuss many different aspects of machine intelligence and robotics related to this topic. There are many deep questions about how we can author/embody a learning system that can become creative, enculturated, and learn about aesthetics. We ask – how will this new machinc aesthetics – or Neosentient Aesthetics play out. Certainly we will continue to make systems that enable human/computer interaction in the service of creative production. At some point in time this interaction may be more like working with a collaborator than a tool.

Seaman gave a paper at Duke on Neosentient Aesthetics. Here he pointed to a form of meta-level discourse that might arise. Topic areas include:

- Discuss aesthetics with the Neosentient in terms of their self-understanding.
- Strange Gödelian loop – where the Neosentient might become creative of such a system with it's own "Catastrophy theory," science of Neo-neosentient Aesthetics; movement to a new 'programmed' aesthetic understanding.
- System might learn to reprogram itself or program other new learning systems.
- Intimidating – creating an entity with its own sense of aesthetics. What might

this be? [23]

In terms of textual aesthetics, Richard Powers in Galatea 2.0. [24] imagined an autonomous machine that learns a sense of poetics though a training in comparative literature. The book is deeply contemplative and through science fiction anticipates many of the ideas surrounding computation and intelligence, and their problematics. Learning in the human is no simple matter to model. When a learning system learns to write its own code, and can anticipate its own future functionality, we might call this a form of Techno-Lamarkism. At the moment such notions are still science fiction.

2.1 Modular codes that could be recombined.

In the short term, Seaman is interested in the authorship of a code generator that would contain many different computer codes with differing functionalities. These could be modular in nature and be designed to be combinatoric. In the past he has called such a system – an *Emergent Intention Matrix*.[25] Each of the modular codes would anticipate a particular kind of functionality, yet the system could combine and recombine these functionalities with an emergent outcome. Imagine an App that generates new Apps…

Summary

We see that there are many forms of anticipation involved with both Computational Creativity and Emergent poetic systems. We witness here the complexity of systems that are in one sense formal, modeled via biomimetics and bioabstraction, and alternately are emergent in nature, thus showings aspects of novelty and surprise. This might be considered the embodiment of a paradox – making a system that is predictive of something which in essence is intentionally not fully predictable. In terms of creativity in the arts, artists do not exactly copy past aesthetic processes. This would be considered un-original. They must often have a relation to art history, to past patterns of creativity. The long-term question is, can we author learning systems that can observe artistic processes which in turn can devise new forms which are emergent in nature. This would be a form of machinic enculturation. Such a system would potentially embody all of the processes discussed above as well as begin to learn how to re-program itself to articulate new creative aesthetics. Such a computational learning system would learn how to be creative.

Bibliography

[1] Rosen, R.: *Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations*, Robert Rosen, 2nd edition, with contributions by Judith Rosen, John J. Klineman and Mihai Nadin, Springer, New York, (2012) Foreword

[2] Foerster, H. von: *Observing Systems* , Intersystems Publication, Seaside California (1981)

[3] Foerster, H. von: *Observing Systems* , Intersystems Publication, Seaside California (1981)

[4] Rosen, R.: *Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations*, Robert Rosen, 2nd edition, with contributions by Judith Rosen, John J. Klineman and Mihai Nadin, Springer, New York, (2012) p46

[5] Rosen, R.: *Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations*, Robert Rosen, 2nd edition, with contributions by Judith Rosen, John J. Klineman and Mihai Nadin, Springer, New York, (2012) p46

[6] Rosen, R.: *Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations*, Robert Rosen, 2nd edition, with contributions by Judith Rosen, John J. Klineman and Mihai Nadin,

Springer, New York, (2012) p72

[7] Rosen, R.: *Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations*, Robert Rosen, 2nd edition, with contributions by Judith Rosen, John J. Klineman and Mihai Nadin, Springer, New York, (2012) p71

[8] Boden, M.:*Creativity and Art, Three Roads to Surprise*, Oxford ; New York : Oxford University Press (2010) p10

[9] ICCC 2013 Sydney Australia, The Fourth International Conference on Computational Creativity, http://www.computationalcreativity.net/iccc2013/ (accessed June 22, 2014)

[10] W. Seaman. "Emergent Constructions: Re-embodied Intelligence within Recombinant Poetic Networks," Digital Creativity 9. 3, pp 153–160 (1998)
paper delivered at Consciousness Reframed conference 1997.

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

[12] Varela, F., Thompson, E. and Rosch, E.:*The Embodied Mind, Cognitive Science and Human Experience*. Cambridge/London: MIT Press. (1991) p23

[13] Locher, P.: *How Does a Visual Artist Create an Artwork* in The Cambridge Handbook of Creativity edited by J. Kaufman and R. Sternberg, Cambridge University Press, for a compendium of empirical approaches to artistic creativity. (2010) 131

[14] Babbage, C.: "Notes by The Translator written to clarify the textual work entitled Sketch Of the Analytical Engine Invented by Charles Babbage by L. F. Menabrea" in *Charles Babbage and his Calculating Engines: Selected Writings by Charles Babbage and Others*. New York: Dover Publications, Inc. p. 249

[15] Seaman, W.: "Recombinant Poetics and Related Database Aesthetics." In Database Aesthetics. Ed. Vesna, V. University of Minnesota Press, (2007)

[16] Seaman, W.: "Recombinant Poetics / Emergent Meaning as Examined and Explored Within a Specific Generative Virtual Environment." VDM press, (2010) (Seaman's PhD thesis originally published 1999)

[17] Conversation with Supko.

[18] Seaman, B. *The Exquisite Mechanism of Shivers*, installation. (1991) See also ARTINTACT, http://on1.zkm.de/zkm/e/werke/TheExquisiteMechanismofShivers, (accessed 2 July, 2014)

[19] Shiffman, D.: Generative Text, http://shiffman.net/teaching/a2z/generative/ (accessed 2 July, 2014)

[20] Howe, D.: RiTa Tool Kit, http://rednoise.org/rita/ (accessed 25 August, 2014)

[21] Kurzweil, R. *The Singularity is Near*, New York, Viking (2010)

[22] Seaman, B. and Rössler, O.E.: *Neosentience / The Benevolence Engine*, Intellect, London (2010)

[23] Seaman, B. "An Embodied Expansion of Neural Aesthetics — The Aesthetics of Neosentience", Your Brain on Art: Probing Neuroaesthetics, Duke University, Durham, North Carolina (2008)

[24] Powers, R. Galatea 2.2.: NY: Farrar Straus & Giroux. London: Little, Brown / Abacus (1995)

[25] Seaman, Bill, *Object-based Emergent Intention Matrix*,
http://users.design.ucla.edu/~fwinkler/PSE/eim.html (accessed 2 July, 2014)