Generative Works:
From Recombinant Poetics to Recombinant Informatics

Professor Dr. Bill Seaman

Professor Dr. Bill Seaman
Media Arts + Sciences
A.AH. & VS, Duke University
Durham, North Carolina
bill.seaman@duke.edu

***Abstract*—Seaman has been active in the creation of differing Cyberworlds from the early 90's onward. This paper will cover historical approaches including *The World Generator / The Engine of Desire* (1996 to present) a generative virtual environment—exploring Recombinant Poetics; *The Architecture of Association* (with Daniel Howe); *Engine of Engines* (Howe | Seaman) (2011 - present); the more recent generative Cyberworld systems — *A China of Many Senses* (2011/2012), and *The Many Senses Engine* (2013 - present); and *The Insight Engine* (2014) exploring Recombinant Informatics — an explatory approach to bisociational transdisciplinary research. He will discuss his collaboration with John Supko – including the co-leadership of the new Emergence Lab at Duke University in the new Media Arts and Sciences program. Seaman also has long term plans related to an integrated network of focused sensing, dynamic virtual environments, recombinant Informatics, and speed of light computation – *The Light-Data Domain*, A collaboration with Tuan Vo-Dinh, head of the Duke Fitzpatrick Institute for Photonics.**

Key Words—computational creativity; virtual world generator; generative environment; Recombinant Poetics; Recombinant Informatics; database system

I. INTRODUCTION — RECOMBINANT POETICS

Works that explore Recombinant Poetics (coined by Seaman in 1995) enable the examination of operative media-elements within specific, construction-oriented virtual environments. Inter-authorship is achieved through use of such systems. Recombinant Poetics is concerned with the combination and recombination of media-elements in the service of generating emergent meaning through interactivity. Context, de-contextualization, and re-contextualization are explored in a dynamic authored environment by a participant operating within the constraints of the authored system. Such environments are characterized by Rhizomatic space (Deleuze and Guattari 1987)[1], and relate to earlier combinatorial exploration of interactive video, as generated via interactive laserdisc and/or digital video[2]. In terms of video functioning as a media-element, a series of potentials are opened up within virtual space[3]. The ramifications of these potentials are relevant to questions of both form and content. It must also be noted that many different artists can be seen to be exploring Recombinant Poetic processes at this time. Such systems often explore aspects of generative functionality as part of the system.

A. Combinatorics

A system can be designed to combine and recombine media materials in differing ways and in different combinations as an ongoing generative process. This generation of differing "configurations" might be brought about within differing kinds of environments including virtual environments, augmented reality environments, interactive video environments, interactive text environments, interactive sound environments, and/or some form of mixed digital space, enabling the generation of configurations of many different kids of media elements and processes.

B. Fields of Meaning

One way of coming to understand combinatoric systems that bring different media elements into juxtaposition and/or superimposition is to explore the metaphor of fields of meaning as borrowed from physics[4]. This new approach to meaning production bears relation to notions of gestalt. That is, a 3-D object might have one meaning, and an image another, and the sonic background that the work is being created in forms another dynamic relation that feeds into the reception of the work. Each media element brings a different 'meaning force' to the equation. Each participant brings the field of his/her own historical relations to different patterns of media experience, and there is an ongoing relational "meaning-summing" that takes into account the different meaning vectors that each media element brings to evocation in a given work. This might be called a Second-Order cybernetic system.

C. Interauthorship: Layers of Authorship Potential

Seaman coined the term interauthorship to point at the potentials of some forms of generative work. The artist/programmer "authors" a particular environment that merges interface, software, hardware, input, functionality, and output within a system that produces limitless unique outcomes. The user of the system adds an individual layer of his/her own 'authorship,' via their choices from the system constraints, exploring the operative potentiality of

that system. A unique emergent outcome arises through their particular interaction.

D. The World Generator / The Engine of Desire (with Gideon May - programmer) 1996 to present [5]

The World Generator / The Engine of Desire was an early generative virtual environment. The original notion was --- could one build a generator of virtual worlds such that one could sit down and instantaneously use an interface system to create and edit 'aesthetic' virtual worlds in real time? Erkki Huhtamo coined the term World Processing for this activity. (conversation with Seaman) Seaman collaborating with the programmer Gideon May authored this complex virtual world generator that enables users of the system to construct and navigate virtual worlds by making choices from a spinning virtual interface of container wheels in conjunction with a physical interface table. These rolodex-like container wheels house a series of different media-elements and processes including 3D objects, 2D images and poetic texts, musical loops, and digital movies as well as processes relevant to altering an entire virtual world. Seaman coined the term *E-phany Physics* to describe a playful, authored, abstract physics [6]. The user of the system can also explore a set of built-in generative chance processes to construct worlds. One can also attach behaviors to the media-elements, apply still and movie texture maps, as well as make the media-elements transparent. When the participant navigates through the virtual world, a new sound mix is made for each user - Seaman calls this Recombinant Music [7]. The work explores emergent meaning and is different for each participant. A networked version of the work has been shown internationally which enables people in two parts of the world to inhabit and operate within simultaneous copies of the same environment, communicate via videophone, and view the alternate participant as a video avatar. This avatar shows the relative position of the alternate participant within the virtual space. A Japanese Version of the work has also been authored and shown in Tokyo at the NTT/ICC Intercommunication Center [8] in conjunction (networked) with a show at the ZKM, Karlesruhe (Center for Art and Media Technology). A third large-scale version has been authored for the Visualisation Portal at UCLA which is visible on a 160 degree screen. This version was driven by (at that time) the powerful "Reality Monster" SGI computer, enabling literally hundreds of objects/images to populate the generative environment simultaneously. Seaman's Ph.D. *Recombinant Poetics: Emergent Meaning as Examined and Explored Within a Specific Generative Virtual Environment* (1999), University of Wales, discusses the work at great length. Additionally Seaman published the *Recombinant Poetics* text in VDM press in 2010. Initially, high-end Silicon Graphics machines were needed to explore the work with no latency.

E. Meta-Meaning Systems

Seaman has been interested in authoring what he calls meta-meaning systems. Such systems enable users to observe meaning as it arises and changes through use of the system. One way of coming to understand combinatoric systems that bring differing media elements into juxtaposition and/or superimposition is to explore the metaphor of 'fields' of meaning as borrowed from physics— a meaning force. This new approach to meaning production bears relation to notions of gestalt. That is, a 3-D object might have one meaning, and an image another, and the sonic background that the work is being created in forms another dynamic relation that feeds into the reception of the work. Each media element brings a different meaning force to the equation. Each participant brings the field of his/her own historical 'pattern' relations to different qualities of media experience, and then there is an ongoing relational 'meaning-summing' that takes into account the different meaning vectors that each media element brings to the evocation of a given work. Thus the work functions as a meta-machinic assemblage (Seaman's coin) derived from the writings of Deleuze and Guattari [9].

II. GENERATIVE WORKS

Generative works of art are works which have a set of rules or parameters that are authored, that when "played out" lead to an emergent outcome. This emergence may be within a small range of outcomes or may be infinite in nature. In general each of Seaman's works have a computational system that is authored that enables the generative aspects of the work to unfold. Generative systems can be used as tools to create portions of works of art which are not in themselves generative in nature. Generative systems may create modules [image/sound/text] (when functioning as tools) that are employed in differing generative system engines or in a linear work. These modules may be image, sound or text. Generative systems are emergent in nature— their aesthetic outcome is not fully known in advance. These systems explore probabilities and often employ chance potentials as drawn from a database of media-elements or processes. We might call the careful choice of media-elements and processes – loading the dice.

A. The Architecture of Association 3.0 – Daniel Howe and Bill Seaman [10][11][12]

The Architecture of Association 3.0 is a collaboration between Daniel C. Howe and Seaman. The work embodies a strong blend of science (Artificial Intelligence and Cognitive Science), technology (a complex generative computational installation) and art (a highly aesthetic, ever changing digital collage – the combinatoric nature of the work, and the number of media elements housed in the database for the work, means that it never

'exactly' repeats). *The Architecture of Association* is a large-scale, generative artwork that draws associative links between disparate video images, and poetic texts to form dynamic and evolving visual and textual collages. A distributed flow of text, image, and video dissolve and "intelligently" become distributed along a series of short-throw projectors, falling seamlessly 360 degrees around a room space, forming an immersive environment. As the work is emergent in nature, it does not repeat sequences of images or texts, but instead forms a continuously recombinant network of 'generated' media associations. This set of linked screens form a complex fully immersive associative unity. Images shot in Seoul Korea form the visual subtext. *The Architecture of Association* builds on this concept of recombination to create a collaged generative media landscape from underlying associations. It seeks to 'point at' associative processes through the employment of meta-tags and computational association. The work passes through particular overall "associative states" including "city"; "forest"; "land"; "elevator"; and "night"; along with its normal functioning. At times the environment is text only…Often the system flips quickly thought hundreds of texts before landing on a 'particular' one.

B. Details of the Functionality – "Intelligent" Positioning of Media Materials [13]

To enable the creation of dynamic associative collages, the Association Engine (AE) stores a range of media elements (text, images, and video, etc.) within a relational database system. An hour long linear soundtrack by Seaman is used with the system. Each media element is tagged with a range of meta-data used to 'intelligently' recognize semantic, linguistic and structural relationships between items. These elements are weighted according to the strength of the association and then situated accordingly between the target concepts. Howe as programmer for the work provides the following technical explanation: "For example, if the engine is analyzing possible relationships between items A and B, it might recognize term C, whose association with terms A and B has strengths of .8 and .4 respectively. C would then be situated in 'association-space' at a distance from A that is twice the distance from B. This represents a simple binary relationship.

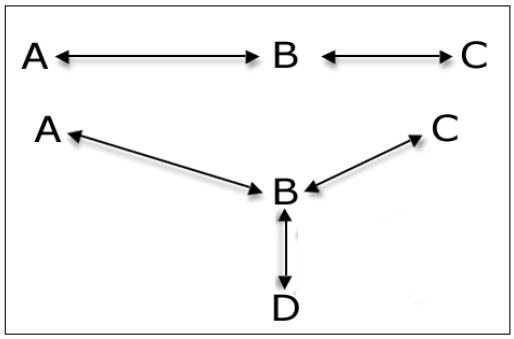

Figure 1. Example of positioning in "association space"

Multiple terms/concepts can interact in such a scenario so that the spatial relationship requires multi-dimensional mapping. These relationships (an undirected graph with edge-weights representing relationship-strengths) are used to dynamically situate new terms within the evolving visual representation so that media elements are appropriately mapped in a dynamic collage. Here, C's relatively strong relation to D shifts it (along the y-axis) away from A and B, though their relative strengths (2-to-1) remain fixed. More complex relationships can be represented similarly in 3 (or more) dimensions."[14]

C. Generative System Function

The work unfolds as follows. An initial random image/word/or short section of text is positioned in a particular zone. The system will then search for an 'appropriate' association in the media database. This process continues over time with each newly added element forming associations both with existing elements and newly 'located' media elements as drawn from the database. Each new element dissolves into the collage in its appropriate position, due to the graph of its associations, potentially across multiple screens. Together, multiple screens form a coherent "associative unity", bridging multiple associated topic areas which flow across the room of screens.

D. Intention

The work employs key-words, meta-data and custom clustering algorithms to make 'informed' selections from the databases, bringing associative material into proximity for a particular duration. These 'informed selections' will create a network of changing relations, stimulating thought and reflection on key concepts poetically related to 'communication'. Thus this 'collage' of associations functions as a generative 'idea bank', with sets of relationships dissolving slowly in across the set of screens, then dissolving away only to be replaced by a new set of media materials drawn from the databases. The system is always generating new juxtapositions. The work seeks to provide a continually changing set of 'intelligent'

associations that are designed to trigger new creative ideas in the minds of viewers. Thus a primary goal of the installation is to continually provoke thought, drawing viewers into active contemplation of their own associative process. Again, this functions as a meta-meaning environment. Where other works might be ignored over time, this work attempts to be provocative in an ongoing manner, continually renewing itself in an emergent fashion.

E. A China of Many Senses (2012) [15]

This artwork is driven by a software engine, written in C++ and OpenGL. In real-time, it uses combinatorics and composes a dynamic set of slowly changing images drawn from a library of disparate media elements, video and image content, 3d models and musical passages, and brings them together in an evocative "painterly" media landscape and computer generated collage. Seaman made a series of trips to China and shot video of both contemporary and historical sites in China, juxtaposing differing cultural qualities. These videos and stills from the video become texture maps in the generative space. Seaman's early text, 2002 – Emergent Explorations of Digital Video in Virtual Space outlines at length the potentials of Video and video stills in virtual space.[16] Seaman also composed a series of modular audio samples to function as the combinatoric generative score. Additionally a generative poetic text was written by Seaman and is included in the work. A series of 3D architectural models were compiled for use in the system, and a series of abstraction algorithms were developed. Different iterations of the work were analyzed and adjusted, focusing on defining a finished sense of the aesthetics informing the work in conjunction with Berreth functioning as programmer and contributing additional design. The work was highlighted in a large showing on the exterior of the Nasher Museum in the Chat Festival. This made the architecture itself feel like it had become mobile and machine-like.[17] The potential is to develop other generative works for uses in foyers of buildings, thus bypassing the use of static sculpture.

F. An Engine of Many Senses (2013) [18]

An Engine of Many Senses is a generative computational work exploring the history and potential future of the computer. It includes a series of media elements that combine and recombine over time -- 3d images, 2d stills, generative audio, generative media "landscapes", generative text and video components. The work has a series of internal rules that play out different combinatoric strategies, as drawn from an extensive database of architectural typologies and processes. In particular the work includes a series of allegorical time-based images of computers as well as collaged images from the history of the computer and computational history in general. It also includes diagrams of systems that have never been built. The text in the work is combinatoric and is displayed across a series of moving glyphs. The work is always different in that it never plays out the same media elements and/or processes. It is an example of computational creativity. The work is emergent in nature. It can be show on a series of high-definition screens, or via projections in architectural settings.

In both *An Engine of Many Senses* and the *Engine of Engines* (see below) a playful attitude was taken to the 'idea' of allegorical imagistic approaches to computation. It was 'eclectically' reflected in the rendering and abstraction of both real and imaginary computers from the history of computation. This included pointing at the *World as Computer* as discussed by Fredkin/Wolfram; the *Von Neumann Machine* (the standard architecture of computers; *the Differential Analyzer* - a beautiful analogue machine that was created by Vannevar Bush; the *DNA Computer*; *Neural Networks*; the *Human as Computer* (humans were computers first!); the *Light Computer* (on the not to distant horizon); the *Memex* by Bush (the beginning of ideas surrounding a media-oriented computation); the *Nano Computer*; the *Electrochemical Computer*; *the Quantum Computer*; the *Self-replicating computer*; the *Electron (Spin) computer*; the *Time Computer*; the *Analogue Computer* or *Maverick Machines* as Pask calls them; and *Wave Computer* - an exploration computation through waves. Alternately, Seaman published a 'science' paper entitled *The Engine of Engine*s, *toward a computational ecology*[19], seeking to literally employ many disparate kinds of computer in a new form of computational network inspired by computation in the body.

III. ABSTRCTED VISUALIZATION

Instead of a normal visualization of Data, one can make poetic interpretations…

A. Engine of Engines – Daniel Howe and Bill Seaman [20][21]

Engine of Engines is an installation comprised of 16 hanging screens, displaying a nervous system-like distributed set of processes. The work explores an allegorical embodiment of non-traditional computers (some real and some imaginary [discussed above]) that form a dynamic reactive network. This network and the activities that take place across it, reflect the larger network traffic in the building, functioning as a reactive computational ecology… although at times local processes set in motion 'self-reflexive' responses. The work has a series of internal rules that play out different combinatoric strategies, as drawn from an extensive database of categorical sets of images. A generative soundtrack forms a parallel layer, and is also responsive

to network traffic and/or human interaction. Unlike other visualizations the work had a series of "eclectic" responses which were akin to "associations" that the machine was making in relation to changes in network traffic. This relates to Howe and Seaman's earlier work - The Architecture of Associations. The viewers of the work were given the knowledge that the system was being reactive to network traffic. They then had to make up their own associations as to what the relationally between network and image set was. Unlike a standard visualization, this set of relations was playful, chance-oriented, non-consistent, erratic, moody, etc. In other words the system reacted more like a human to the traffic than a standard visualization, although the sound had the most direct link, speeding up and slowing down at different times. The work thus took on a "character" of its own. One could even think of this as a new form of "human" abstraction when considering art history. Another strategy was the use of highlighting images that playfully reflected the highest level of network traffic, as if we were zooming in on a particular activities and showing an abstracted "association" that represented them. A third strategy was the creation of a "pattern" that reflected certain "patterns" of activity. Again, this explored moments of pure abstraction to reflect certain qualities of use. Unlike a standard visualization, the relationship between the media ecology and the building's activities were not "spelled out" but became part of the associated thought of the viewer.

IV. RECOMBINANT INFORMATICS

A. *The Insight Engine (2014)* [22][23]

The Insight Engine seeks to draw on my long history as a media researcher designing new forms of interface and qualities of interactivity, and to expand this via a strong interdisciplinary collaboration that bridges Neuroscience, Computer Science, the Arts and Humanities at Duke as well as through international collaboration. Such a project reflects clearly the interdisciplinary goals of both DIBS (The Duke Institute for Brain Sciences who funded the work) and the research community at large, and in particular presents a multi-perspective approach to knowledge navigation and subsequent knowledge production. This research seeks to work toward the digital authorship of a tool to empower insight production, distributed interdisciplinary team-based research and to potentially enable bisociational processes as discussed by Koestler in *The Act of Creation*: "I have coined the term 'bisociation' in order to make a distinction between the routine skills of thinking on a single 'plane', as it were, and the creative act, which, as I shall try to show, always operates on more than one plane…" "We learn by assimilating experiences and grouping them into ordered schemata, into stable patterns of unity in variety. They enable us to come to grips with events and situations by applying the rules of the game appropriate to them. The matrices which pattern our perceptions, thoughts, and activities are condensations of learning into habit […] The bisociative act connects previously unconnected matrices of experience…"

If we reverse engineer differing research communities across multiple disciplines we can assume that many researchers undertake similar practices— reading papers, viewing diagrams, exploring data sets, creating and viewing visualizations, annotating research materials, watching videos, and partaking in discussions among other activities. Interdisciplinary research also means crossing "linguistic" domains framing that research. Here the generation of shared language (developing bridging languages) is essential. Yet, could we make a new system that heightens the potential for insight and creative juxtaposition of essential ideas that cut across multiple research communities/domains? The notion here is to explore Neuroscience/AI/Learning Systems/Neosentience (see Seaman and Rossler's Book - *Neosentience | The Benevolence Engine*) through the associative "lens" of focused computational interactivity, functioning in the service of providing new insights and associations across interdisciplinary research fields, as well as exploring different concepts and foci from within individual research domains. In this instance artfully displayed interactive informatics represents the outermost level of the system. The web based interface enables a user-centric experience, "driving" the generation of a visual set of associative experiences —calling up different words, phrases, titles, images, videos, urls, and models as a network of potential associations that are brought into visual proximity. Such a work functions both on a local level in a visual installation, as well as on a laptop driven across the internet, forming a vast community of contributing researchers.

Outwardly, the initial experience is aesthetic and participatory in nature— the system is designed to be focused in different user-driven directions. Thus, though a network of "pre-seeded" choices (the first year of research) one can drive the system to focus on Neuronscience-only related topics of association. Alternately one can juxtapose texts and images from the arts and humanities — poetic texts, critical/social texts, texts related to ethics, or historical texts from multiple fields— this depends on the choices of the interactant. I describe this as a multi-perspective approach to knowledge production.

One can also select from a scrolling list of researcher/ topics. The media objects that populate the system's database include applications, audio, databases, documents, drawings, images, video sections, quotations, models from multiple fields, and linked websites. Abstracts are also attached for each media object. Thus, we begin with a "seeded" database of diverse materials as contributed by this particular research community - Seaman contacted each of the researchers to participate in

this first year of authoring the system, although as the system is opened up to others (and other research communities), these communities will grow more organically. This database can be added to in an ongoing manner. By digitally "scraping" the searched paper or key word references for media objects, the system can gather, store and enable different qualities of experience to be articulated, related to that information—the system enables instant access to the media objects. Thus the system functions as an iterative learning system. Multiple researchers with the same login can work in a distributed manner, making queries and or calling up past queries. One can create new "vortices" and store papers and/or media objects for future reference. A second menu system enables users to explore a series of lists of key words and concepts, as another associational trigger. These include key words drawn from the researcher's own papers (in blue) as well as lists that Seaman developed to stimulate thought and insight. A random button lets the user generate random texts as derived from the lists. These key word / concepts can also be stored with the users profile. Thus all choices and use of the system can be stored by individuals making up the research community.
All of the papers and media objects are statistically analyzed for word use and enable the weighting and chooses that are derived through bisociational queries made by the user.

Thus the insight engine is a vehicle for developing a community of researchers who might not normally find each other, given particular publishing domains. It stimulates the generation of a community of communities and in particular enables research into ideas which cross disciplinary boundaries. To my mind this is where often the most exciting new forms of research take place.

V. THE EMERGENCE LAB — (CO-RUN WITH JOHN SUPKO)

The Emergence Lab is a new lab co-directed by John Supko and Bill Seaman in the new Media Arts + Sciences program at Duke University, Durham, North Carolina. The Emergence Lab focuses on new media creation (music/sound design, text, still & moving images, etc.) via cutting-edge software processes as well as via poetic generative analogue processes. Seaman and Supko (from the Music department at Duke) co-teach a class in Generative Arts: "This course investigates the intersections of art and computers, art and systems, art and embodied intelligence. We study and make artworks (music/sound art, text, images) that arise from a variety of generative processes. The purpose of this course is to find new & unexpected ways of being artists."[24]

VI. THE LIGHT DATA Domain [25]

As one surveys the field of contemporary sensing, communication and computational research, one sees a number of different research areas that each explore the use of light as a process-related vehicle. If we begin to connect the dots between these different research areas, does this suggest a new holistic paradigm shift? Here different modalities of light may potentially function in concert to achieve a cybernetic cycle flowing from multi-modal sensing system to computational system to memory and database systems to visualization systems and virtual reality, back on to the observer, who programs, designs, and interacts with the systems within a dynamic distributed network of intra-actions. Where some have felt that we have reached the end of Moore's Law, might the use of light in new technologies function as a means to transcend current electron-based methodologies? Does this suggest a radical shift from the electron to the photon as a contemporary physical propagation mechanism for data? Why would this be of interest? What are the unique qualities of light that play into this paradigm shift? We will call this holistic network of technologies and processes the light-data domain. This will be discussed in a future paper written with Tuan Vo-Dinh, head of the Duke Fitzpatrick Institute for Photonics.

VII. SUMMARY

Seaman has above shown many perspectives related to the production of differing Cyberworlds exploring *Generative Works: From Recombinant Poetics to Recombinant Informatics*. He explores many operative ideas in his works, in particular in his interactive works he often explores meta-meaning systems. The generative works grew out of generative programming in the meta-meaning works, but more specifically explore computational creativity — where the system actually draws on data-base media material and a series of focused operative processes, and builds the work on the fly. Future work explores new forms of sensing and light-transduction functioning in the service of multi-modal interaction, generative functionality, and new approaches to learning systems that couple multi-modal sensing systems with robotic computational devices and/or installations of differing kinds.

[1] Deleuze, G. and Guattari, F. (1987), *A Thousand Plateaus: Capitalism and Schizophrenia, vol. 2* (trans. Brian Massumi), Minneapolis: University of Minnesota Press.

[2] See Seaman, B. http://www.billseaman.com (accessed 7 June, 2014)

[3] Seaman, B. (2002) *Recombinant Poetics: emergent explorations of digital video in virtual space* in "Transluminations: New Screen Media Narratives" edited by Zapp and Reiser, BFI Publishers

[4] Seaman, B. (2010), *Recombinant Poetics: emergent meaning examined and explored within a specific virtual environment*, Berlin: VDM Press.

[5] Seaman, B. (2010), *Recombinant Poetics: emergent meaning examined and explored within a specific virtual environment*, Berlin: VDM Press.

[6] Seaman (2000) *Motioning toward the emergent definition of E-Phany physics* http://projects.visualstudies.duke.edu/billseaman/textsE-phany.php (accessed 7 June 2014)

[7] Seaman, B. (2010), *Recombinant Poetics: emergent meaning examined and explored within a specific virtual environmen*, Berlin: VDM Press.

[8] Seaman (1998) http://www.ntticc.or.jp/Archive/1998/PORTABLE_SACRED_GROUNDS/Works/the_world.html (accessed 7 June, 2014)

[9] Deleuze, G. and Guattari, F. (1987), *A Thousand Plateaus: Capitalism and Schizophrenia, vol. 2* (trans. Brian Massumi), Minneapolis: University of Minnesota Press.

[10] Version 1.0 premiered at the MIS Museum (The Museum of Image and Sound) Sao Paulo, Brazil, 2008; Version 2.0 was premiered at the *Dans La Nuit, Des Images*, Grand Palais, Paris (in conjunction with Le Fresnoy), featuring twelve vertically-oriented large-scale plasma displays. A voice-over description is included on the DVD with video documentation from the site. A linear audio score by Seaman loops continuously ever hour as the video and text are generated. This can be on or off.

[11] Howe | Seaman – *The Architecture of Association* 3.0http://projects.visualstudies.duke.edu/billseaman/seamanhowe/aoa/aoa.htm (accessed 7 June, 2014)

[12] At Renci. (Renaissance Computing Institute, Chapel Hill, North Carolina)

[13] In discussion with Daniel Howe. We have used this text in the past to be presented with the work.

[14] Text taken from the Textual description of The Architecture of Association, Howe | Seaman.

[15] Bill Seaman with Todd Berreth, A China of Many Senses, http://vimeo.com/36984212 (accessed 6 June, 2014)

[16] W. Seaman. "Recombinant Poetics: Emergent Explorations of Digital Video in Virtual Space." *Transluminations: New Screen Mediia Narratives*. Ed. Zapp and Reiser. BFI Publishers, 2002.

[17] A China of Many Senses, Nasher Museum, http://vimeo.com/36984212, accessed June 10, 2014)

[18] Bill Seaman with Todd Berreth, http://athanasius.trinity.duke.edu/projects/ems/ems.html (accessed 6 June 2014)

[19] W. Seaman, *The Engine of Engines - Toward A Computational Ecology*, in Integral Biomathics: Tracing the Road to Reality - Proceedings of ACIB'11 Conference in Stirling, Scotland, August 29-31, 2011 and iBioMath'2011 Workshop at ECAL'11, Paris., edited by Edited by P. L. Simeonov, L. S. Smith, A. C. Ehresmann (Eds.).. (Winter, 2011) (July 13, 2012), ISBN 3642281109

[20] Daniel Howe | Bill Seaman - 2012 "The Burning Edge: Making Space, Activating Form", Run Run Shaw Creative Media Centre, City University of Hong Kong

[21] Engine of Engines Documentationhttps://www.youtube.com/watch?v=8F18GYgS5cU (accessed 7 June 2014)

[22] *I_E | Insight Engine* — Bill Seaman research/learning system. Custom software written in HTML5/Javascript/PHP w/database scripted back-end;
Bill Seaman, principle investigator and media researcher; Todd Berreth, design consultant & front-end developer; Olivier Perriquet, research consultant - mathematical modelling / computational linguistics;

[23] *Insight Engine*, http://athanasius.trinity.duke.edu/projects/I_E/i_e.html (accessed 6 June, 2014)

[24] Course description written by Supko in discussion with Seaman.

[25] In discussion with Tuan Vo-Dinh, PhD, Director, Fitzpatrick Institute for Photonics, Duke University;