Toward the Production of Nano-computers and in turn Nano-related Emotive Virtual/Physical Environments

Bill Seaman

The title of this conference - Emotional Architectures / Cognitive Armatures makes us focus on our experience with technological tools as well as our potentially embodied experience with dynamic forms of media-elements and processes. We also become aware of the physical emotive ramifications that such extended environments might generate. There is also an incredibly rich territory that looks at cognitive processes and how they are augmented and/or addressed via technology. The continuum between the physical world and the conceptual world is addressed through the potential of the computer to call forth images, sounds, texts, haptic processes, media-behaviors, robotic movements and even architectural reactivity, via numerous forms of interface. This suggests a constant need to reflect on how we can focus the potentiality and functionality of technological environments, be they local or distributed, to enable interactivity that includes a rich degree of openness and an emergence of resonant experience.

It is important as a new media technology is being born to take an active role in defining its potential functionality. I will here begin to address a series of research questions that surround the production of Nano-computer generated virtual/physical environments. I believe Nano-technology will greatly impact the world, perhaps shifting us into an entirely new age.

Hodges, Turings biographer spoke about the notion of the Universal Machine.

> ...underneath here lay the same powerful idea that Gödel had used, that there was no essential distinction between "numbers" and "operations on numbers". From a modern mathematical point of view, they were all alike symbols. With this done, it followed that one particular machine could simulate the work done by *any* machine. He [Turing] called it the *universal* machine. It would be designed to read description numbers, decode them into tables and execute them. [1]

If we map this concept onto nano-technology and its ability to restructure environments on the deepest physical level, we observe an incredible shift in human-kinds relation to nature. Literally the underlying code of nature becomes operative through nano-processes that function within the elusive boundries of the laws of physics. I believe Nano-computers and the related environments that they will enable will play an extremely important role in terms of the production of Emotional Architectures as well as Cognitive Armatures in the years to come.

It appears that there may be a series of different approaches to how nano-computers might be brought into existence as well as function. My research has centered on a series of different writings from Eric Drexler beginning in the 1986 with *Engines of Creation*[2]. It is interesting to note that Drexler ended up in the Media Lab for his Ph.D. with none other than Marvin Minsky[3] as one of his advisors — can we here begin to picture a nano-related *Society of Mind*.[4] Will nano-computers perhaps function internally augmenting thought processes in some manner?

As potentials of nano-machines were being hotly debated -- Ed Regis states that Drexler's ongoing Ph.D. and it's place of origin was for the most part kept quiet[5]. Yet the Media Lab connection certainly suggests a field of ramifications in terms of nano research in respect to the future of computing; a relation to new media potentialities as well as a relation to artificial intelligence, given the background of Minsky's thought.

In terms of my research I have also become interested in Richard P. Feinman's seminal paper "There's Plenty of Room at the Bottom" [6], December 29th 1959, Drexlers texts *Nanosystems: Molecular Machinery, Manufacturing, and Computation*[7], as well as the internet publications of Drexler's Foresight Institute[8], a plethora of papers on the internet, and a book called *Nano !*[9], 1998 by Ed Regis. I also found the science fiction *book The Diamond Age*[10], 1996 by Neil Stephenson a very compelling take on the subject.

It seems that a shift has recently come about in terms of the skepticism that initially surrounded the potentials of nano-technology, where even "Scientific American"[11] has focused an entire issue on the topic. Huge research initiatives are now underway in many different countries. UCLA is becoming one of these research sites. So again I stress the need to articulate different forms of humanist involvement in research even in this early stage of development.

I spent the last year researching for a hybrid dance/installation work that poetically explores the subject of Nano-technology entitled "Inversion"[12] - a collaboration with the dancer Regina van Berkel. In the process of creating this work I spent much time thinking about virtual environments that might be produced with both nano and quantum computers. It is important to note that I am presenting here from the perspective of an artist/researcher and not as a scientist[13] — although I am hoping that this paper will stimulate a trans-disciplinary set of research agendas that might attract scientists, artists, architects, and designers to begin to think about the social and communicative potentiality of such computational spaces and their highly dynamic relation to the lived environment.

I want to begin to lay out a trans-disciplinary plane or plateau of research agendas and start to answer questions over time one by one; as well as to begin to define a diverse team, where each person can bring a different expertise to the table. I am seeking to pull together disparate researches to construct a new kind of computing environment capable of generating a very robust form of virtual environment, one that functions in tandem with physical space. Such a space may be interfaced from outside the body or possibly (in the very long run) in some manner — internally. I have a number of problems with some of the ideas presented by such writers as Raymond Kurtsweil in his book *The Age of Spiritual Machines*[14], yet already research is ongoing related to the internal biological use of nano-mechanisms in the medical field.[15]

The big problem. First — How do we make a nano-computer? Following Drexler's insights we might explore an approach that would involve a timed set of chemical reactions, constructing a complex assemblage of molecules that could potentially define a form of bio-mechanical computer. Drexler states: "*Molecular Manufacturing* is the construction of objects to complex, atomic specification using sequences of chemical reactions directed by nonbiological molecular machinery. *Molecular nanotechnology* comprises molecular manufacturing together with its techniques, its products and their design analysis; it describes the field as awhole. *Mechanosynthesis*- mechanically guided chemical synthesis-is fundamental to molecular manufacturing...[16]

Drexler is interested in part in defining a range of nano- mechanical processes by taking the metaphor of particular mechanical machines, machine parts and processes and mapping those metaphors onto potentialities of the nano arena. He has already described the potential construction of a nano-computer. There is much healthy debate about Drexler's approach and the complexity of the physics which dictate such a paradoxically small and large undertaking. Yet Drexler has a visionary and pragmatic approach that I believe will be very fruitful in the long run. Irregardless if one ascribes to his particular methodology one can begin to consider how to assemble a bio-mechanical computer with atomic scale working parts. In terms of Drexler's research, Regis' book[17] moves through a history of a number of instances where skepticism was overtaken by the veracity of hard science.

It seems ironic but many answers to developing mechanical computers in nano-space may lie in re-understanding the first computers that were created by Charles Babbage and programmed by Ada Lovelace. In particular some of the workings of the Difference Engine and the Analytical Engine could be viewed in a metaphorical manner and re-applied to this nano-context. (Drexler also stated this in his writing.)where?

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 enlightened remarks presented initially in 1842:

> 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.[18]

This intuition is extremely rich in the context of computer-related emotional architectures. In particular I find it exciting that she is discussing the aesthetic potential for such a device.

In terms of computing we seem to be on the cusp of a paradigm shift in relation to nano-production that moves toward biological metaphors and functional biological processes.

Might we chemically "fold" some of the parts of such an "operative" mechanism into existence? In the book *Metaphors we Live By*[19], Lakoff systematically shows the importance of metaphor to our understanding of reality. Drexler is well aware of the huge jumps we have made in terms of the Human Genome in relation to the operability of atomic scale processes within particular solution environments. In *Nano*, Regis presents the following concept:

> The most remarkable feature of a protein molecule, however, was the fact that the sequence of its component amino acids caused the molecule to fold into a given shape. That was the term biologists used to describe the way in which an amino acid string behaved once it was placed in water and let go: the string kinked up, curled around, twisted, crimped, and folded back upon itself in highly individual and specific fashion. The shape of the fold was determined by the precise order in which the different constituer amino acids were distributed along the chain. [20]

So we can begin to see a way to literally "fold" the functional parts of our nano-computer into existence. There are "Two protein folding problems: one was that of predicting the shape of a fold; the other was that of causing a fold to happen."." [21]

In the prologue to "Nano" Regis states: "There was a design that worked perfectly, a gear system that was made out of 3,557 atoms precisely that many, not one more and not one less. Every separate atom was placed just so. All the chemical bonds were correct."[22] He also stated that " One particular (folding - emphasis Seaman) sequence led to a particular structure, reliably, every time"[23]. There are many difficulties in studying the underlying mechanisms of this form of bio-technological approach. We can however potentially become aware of how certain sequences of amino acids might in time behave with a high degree of predictability. So how can we build a functional computing machine out of these bio-operative processes? How can we make inter-operative such a technology with other existing and new technologies?

Regis goes on to say "Nevertheless, that (the folding paradigm emphasis seaman) in essence was Drexlers Plan for creating a race of molecular machines: sequence the right amino acids together and thereby create a marvelous new protein to order. Create enough of those proteins of the right size and shape, and they' d assemble themselves into a workable device - into the molecular machine of your choice."[24]

Although this sounds quite difficult at this time, in the long run this kind of biological approach to making nano-computers may have more potenital than other top down approaches related to the current manufacture of chips. Drexler states:

> Development of the ability to design protein molecules will open a path to the fabrication of devices to complex atomic specification. This path will involve construction of molecular machinery able to position reactive groups to atomic precision. It could lead to great advances in computational devices and in the ability to manipulate biological materials. [25]

There is a huge debate surrounding Drexler's nano-robot assemblers and their physically impossible "sticky fingers."[26] Debates also focus on nano-robots that might function autonomously, building other nano-bots which in turn might restructure natural materials. In the wrong hands or through some programming error, such a world of devices might reak havoc on the lived environment. We must now begin to define an ethics surrounding nano-computation and its physical ramifications. It is important to develop a humanist debate surrounding the awe-inspiring potentials of this technology.

Because we will in the beginning want to define a hybrid chip/nano platform, it will most likely be a mix of top down and bottom-up approaches that will enable the construction of these tiny computers. One can imagine computing architectures that are both constructed through a top down "printing" paradigm which is described at length in the Scientific American - Nanotech issue, with parts being constructed also through the bottom up "solution environment" suggested above.

(Carl Pabo) Pabo spoke of Drexler, having suggested an inverted approach in which "rather than starting with an amino acid sequence and then predicting the conformation of the folded polypeptide, one starts with a conformation of the backbone and then picks an amino acid sequence that should stabilize it".[27]

Drexler states:
"Intermolecular attraction between complementary surfaces can assemble complex structures from solutions." He also articulates the notion that "Gene synthesis and recombinant DNA technology can direct the ribosomal machinery of bacteria to produce novel proteins, which can serve as components of larger molecular structures." He truely believes that "Molecular assemblages of atoms can act as solid objects, occupying space holding a definite shape. Thus, they can act as structural members and moving parts."[28] Here is a table that presents some of the operative mechanical metaphors.

Comparison of Acroscopic and Microscopic Components[29] :

Technology	**Function**	**Molecular Example**
Struts, beams, castings	Transmit force,	hold positions Microtubules, Cellulose, mineral structures
Cables	Transmit tension	Collagen
Fasteners,	glue, Connect parts	Intermolecular forces
Solenoids, actuators	Move things	Conformation - Changing proteins, Actin/myosin
Motors	Turn shafts	Flagellar motor
Drive Shaft	Transmit torque	Bacterial Flagella
Bearings	Support moving parts	sigma Bonds
Containers	Hold Fluids	Flagella, membrane proteins
Pipes	Carry Fluids	Various Tubular structures
Pumps	Move Fluids	Flagella, membrane Proteins
Conveyor belts	Move components	RNA moved by fixed Ribosome (partial analogue)
Clamps	Hold workpieces	Enzymatic building sites,
Tools	Modify workpieces	Metallic complexes,
Functional groups	Production Lines	Construct devices Enzyme systems, ribozomes
Numerical Control systems	store and read	Programs genetic system

So we then ask how might such a computer be controlled? Drexler states "As present microtechnology can lay down conductors on a molecular scale and molecular devices can respond to electric potentials (through conformation changes, etc.) such devices can be controlled by human operators or macroscopic machines."[30]

In an article entitled "Plenty of Room Indeed", Michael Roukes suggests that there is also the potential of communicating with the device through other means..."...to usefully track the device's vibrations, the ideal NEMS transducer must be capable of resolving extremely small displacements, in the picometer-to-femtometer (trillionith to quadrillionth of a meter) range, across very large bandwidths (extending into the microwave range." He goes on to say, "Ultimately , the technology will depend on robust, well engineered information transfer pathways from what are, in essence, individual macromolecules. [31]

So the question becomes how can we take the present metaphor of the generation of virtual space and enable authorship utilizing entirely new nano-computational devices?

I would now like to lay out a series of research questions.
What new kinds of operating systems would we like to see in such environments?
What kinds of object-based code tools can be authored to augment the programming of such realms?
How do we functionally connect the human scale environment of media production as well as develop new models of connectivity to this scale of computing processes?
How can we make these computers function such that they can provide very fast refresh rates for virtual environments?
What will the best nano-storage of data be?
How might this environment enable us to observe its functionality in a diagnostic manner?
What kinds of new output strategies might be used to deliver these virtual worlds?
Might nano-technology also enable new viewing apparatus with incredible, atomic scale resolution?
What new interface stratgies might nano-production enable?
How can we make it easy to author media-environments and make them responsive to real world input?
How can new sensing paradigms function in a connective intelligent manner with media elements housed in nano-computers?
In general, how might such computers augment thought processes?
To what end can these devices be used for emotive media production?

1. A. HODGES, *Alan Turing: The Enigma* (New York: Simon and Shuster, 1983) , p.104

2. Eric Drexler, *Engines of Creation*. (Anchor Books, 1986)
See also http://www.foresight.org/EOC/ for a web version of the book

3. See the on-line Forword to *Engines of Creation* by Marvin, Minsky at http://www.foresight.org/EOC/EOC_Foreword.html

4. Marvin, Minsky, *Society of Mind* (Simon and Shuster, 1988)

5. Ed Regis, Nano!, (Little/Brown, 1995) It must be noted that I have taken a number of quotes from Nano in that they present the topic in a manner which is formed for a broad audience.

6. Richard P. Feynman, "There's Plenty of Room at the Bottom" A transcript of the classic talk that Richard Feynman gave on December 29th 1959 at the annual meeting of

the American Physical Society at the California Institute of Technology (Caltech) was first published in the February 1960 issue of Caltech's Engineering and Science, which owns the copyright. It has been made available on the web at
http://www.zyvex.com/nanotech/feynman.html
For an account of the talk and how people reacted to it, see chapter 4 of Nano! by Ed Regis, Little/Brown 1995

7. Eric Drexler, "Nanosystems: Molecular Machinery, Manufacturing, and Computation", (Wiley, 1992) In particular see Chapter 12, Nanomechanical Computational Systems starting on p. 342.

8. See on-line Drexler's Foresight Institute, http://www.foresight.org/index.html

9. Ed Regis, Nano!, (Little/Brown, 1995)

10. Neil Stephenson , *The Diamond Age*, (Bantam Books, 1996)

11. *Scientific American* Special Issue, "Nanotech", September 2001

12. For More information on"Inversion" see
http://www.rheintanzmedia.net/webpages_e/inversion.htm

13. See also http://www.cda.ucla.edu/faculty/seaman/

14. Ray Kurzweil*, The Age of Spiritual Machines :When Computers Exceed Human* (Penguin, date)
See also
http://www.penguinputnam.com/static/packages/us/kurzweil/excerpts/exmain.htm

15. "Less is More in Medicine" by A. Paul Alivisatos
Scientific American Special Issue, "Nanotech", September 2001

16. Eric Drexler, "Nanosystems: Molecular Machinery, Manufacturing, and Computation", (Wiley, 1992), p. 1

17. Ed Regis, Nano!, (Little/Brown, 1995)

18. Charles Babbage, *Charles Babbage and his Calculating Engines: Selected Writings by Charles Babbage and Others*. (New York: Dover Publications, Inc.,1961), p.249

19. George Lakoff and Mark Johnson, *Metaphors we Live By*, (University of Chicago Press, 1980)

20. Ed Regis, Nano!, (Little/Brown, 1995), p. 93

See Also Eric Drexler, "Nanosystems: Molecular Machinery, Manufacturing, and Computation", (Wiley, 1992)

21. Ed Regis, Nano!, (Little/Brown, 1995), p. 115

22. Ed Regis, Nano!, (Little/Brown, 1995), prologue

23. Ed Regis, Nano!, (Little/Brown, 1995), p. 39

24. Ed Regis, Nano!, (Little/Brown, 1995), p. 94.

25. Ed Regis, Nano!, (Little/Brown, 1995), p. 101
See also 1981 issue of Proceedings of the National Academy of Sciences. See also Eric Drexler, "Nanosystems: Molecular Machinery, Manufacturing, and Computation", (Wiley, 1992) p. 343

26. See Richard E. Smalley, "Of Chemistry, Love and Nanobots", *Scientific American* Special Issue, "Nanotech", September 2001, p. 77
See also George M. Whitesides, "The Once and Future Nanomachines", ", *Scientific American* Special Issue, "Nanotech", September 2001, p. 81

27. Ed Regis, Nano!, (Little/Brown, 1995) p. 101

28. Ed Regis, Nano!, (Little/Brown, 1995) p. 101

29. Ed Regis, Nano!, (Little/Brown, 1995) p.104
See also Section 11.6 of Eric Drexler, "Nanosystems: Molecular Machinery, Manufacturing, and Computation", (Wiley, 1992)

30. Ed Regis, Nano!, (Little/Brown, 1995) p.104

31. Michael Roukes, "Plenty of Room Indeed" *Scientific American* Special Issue, "Nanotech", September 2001 p. 55-56

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