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Practical Uses of Nanotechnology to Accelerate Design Innovation.

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Nanotechnology promises a natural method to accelerate the complex task of innovation for many design problems by exploiting self-assembly and quantum processing at extreme scales of miniaturization. With this objective, a range of hybrid computer devices that use biological cells or chemical thin-films have been built to take advantage of nanoscale information processing. These devices are termed molecular computers and function by manipulating input sets of digital schematics or images stored to compact-disc optical media. Light transmission through cells or chemical thin-films is a highly nonlinear phenomenon, and causes digital information to replicate with itself. This means that well-defined input sets evolve into entirely new sets through mutation, crossover and natural selection at the atomic level. Each bio-nanocomputer is therefore a computationally intensive, yet high-speed, controlled chaotic feedback system, used to deconstruct, then reconstruct form. Methods to optimize device construction have been previously reported.

Several questions underpinning the formal nature of the design process have been identified in these experiments. For example, what would happen if a designer could access a near-infinite number of different design variations? How does the designer make choices under these conditions? What is the relationship between form and function at the atomic level? When is a computation complete? Do discrete spatial modifications lead to multi-dimensional change?

The Approach

In this study we examine design strategies incorporating bio-nanocomputing as a key tool in the primary conceptual development stages of two alternative new product development processes. Each experiment was conducted in a context intended to represent alternate modes of industry practice. The first experiment involved an independent design consultant utilizing molecular computing as a separate member of the design team. Following bio-nano manipulation, digital images of prototype furniture forms were returned to the designer and used as a catalyst to generate and refine further variations. This process was repeated until the designer determined that one of the resulting concepts had reached an appropriate stage of evolution. The concept was then detailed for production and prototype construction. The resultant furniture form physically embodies the decision making process employed by the designer derived from engaging in conversation (programming) with a molecular computer. The second experiment involves cooperation with Electrolux, who represent the largest in-house industrial design team in Australia. The team is solely responsible for continually providing new generations of products for the largest electrical appliance manufacturer in the world.

Indication of Main Findings

This paper also demonstrates, by way of two case studies, the extent to which molecular computing can be used as a commercial tool within the product development process. The design team utilized output results generated with molecular computing in a variety of alternative ways; however all acted as stimuli in the development of intellectual property linked to the new product development process. Our research includes an honest appraisal of the extent to which nanotechnology can add to the act of creativity and how, for some designers, initial interaction was non-rewarding. Both positive and negative aspects of interacting with this technology are discussed including the extent to which it was culturally accepted within the design communities linked to both case studies. The paper concludes by offering recommendations as to how this application of nanotechnology can be utilized in its present form, and how future improvements could provide further benefits to industry. The research also provides an opportunity to reconsider the act of designing within a commercial context.

Practical Uses of Nanotechnology to Accelerate Design Innovation

Abstract

Nanotechnology promises a *natural* method to accelerate the complex task of *innovation* for many design problems by exploiting self-assembly and quantum processing at extreme scales of miniaturization. With this objective, a range of hybrid computer devices that use biological cells or chemical thin-films have been built to take advantage of nanoscale information processing. These devices are termed *molecular computers* and function by manipulating input sets of digital schematics or images stored to Compact Disc optical media. Light transmission through cells or chemical thin-films is a highly nonlinear phenomenon, and causes digital information to replicate with itself. This means that well-defined input sets evolve into entirely new sets through mutation, crossover and natural selection at the atomic level. Each *nanocomputer* (whether constructed with biological cells or chemical thin-films) is therefore a computationally intensive, yet high-speed, controlled chaotic feedback system, used to deconstruct, then reconstruct form. Methods for generic device construction have been previously reported, so here we focus on the implementation details for approximating several simple design models; before moving on to demonstrate the method against three-dimensional forms such as furniture.

Several questions underpinning the formal nature of the design process have been identified in these experiments. For example, what would happen if a designer could access a near-infinite number of different design variations? How does the designer make choices under these conditions? Are pragmatic attributes of concept development such as ergonomic considerations, manufacturing capabilities and material selection marginalized? If so, how does a designer usefully employ this process?

The Technology

The aim of this paper is to demonstrate how to rapidly evolve new designs by taking advantage of quantum entanglement in Compact Disc based systems. This bold statement is supported by theory and empirical evidence. Our particular domain of interest deals with practical strategies to manipulate digital information in a machine-based manner with the aim to rapidly synthesize new arrangements of value to the design community. Our premise is that a limitless number of design objects can be permuted for any bivalent (true/false) input; where mutated structures develop during quantization error propagation. This nonlinear cocatenation of fragments during output from the algorithm is mathematically well formalised by the encoding principle used in compact disc storage. This seeks to minimize errors by using a complicated series of steps to firstly distribute contiguous information into smaller packets, and then sub-sample their content to maximize information integrity as a lossless whole.

Our approach actively promotes error, yet does so at a resolution level below that which most designers normally work with (10^{-6}–10^{-9}m). It is stressed that we are not talking about simply iterating fixed regions of interest or crude mistakes like ‘the wrong colour’, or ‘the wrong surface finish’ and just collecting these design objects like output from a fixed fractal generator. Rather, we take advantage of the principle of fractal feedback at the digital level by modifying the algorithm continuously during the computation. We do this by constructing an optically nonlinear, barrier-gate filter on the compact disc data surface.

What Does a Designer Need to Know and How Do They Use the Technology?

The nano-approach is aimed to be integrative into the day-to-day design process. We begin by considering design objects to be represented by any kind of discrete information that can be formalized digitally. In this paper we restrict ourselves to design objects that can be described or represented by two-dimensional images, yet previous results confirm the method to work with sound[1].

The system operates using nonlinear optical scattering[1-2] and plasmon wave resonance[3] on the surface of compact disk media[4]. Error correction is used as a driving mechanism to inject pseudo-randomness during feedback. New string output of digital schemata reveals detail at both local and global levels of organization. However, this has been achieved without first-order iterative fractal or affine transformation, nor using genetic programming[5]. The results are completely defined by quantization error coupled with plasmon wave resonance. This paper cannot do justice to the elegant mathematics and physics underpinning this approach, therefore we draw the readers attention to the original literature[6]. In summary, optical instability occurs when laser light passes through cells or chemical thin-films causing digital information to replicate with itself. This means that well-defined input schematics evolve into entirely new sets through mutation, crossover and natural selection at the bit level.

The Approach

A vast array of alternative design strategies have been developed to assist in optimizing the conceptual development of appropriate solutions that meet the specific contextual requirements of individual client needs. Whilst certain strategies are generic with transferable properties, others are idiosyncratic relating to unique sets of circumstances. Such strategies offer guidelines relating to best practice but refrain from attempting to provide a formulaic approach to the creative thought process. Our intention is to therefore examine design strategies incorporating bio-nanocomputing as a key tool in the primary conceptual development stages of alternative designers and design teams rather than industry or discipline sectors. Each case study does however represent circumstances in which the pragmatic issues that surround the design process are of an ever-increasing level of complexity. Detailed visual results for each case study are available[7].

Case Study: Bauhaus Revisited.

The work of the Bauhaus largely concerned itself with synergies between disciplines previously considered only as separate entities; a union between fine art, science and industry, which

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[1] Jones, C.L. (2004). Sound and Image Processing with Optical Bio-Nanocomputers: Implications for Molecular Computing of Digital Information. Problems of Nonlinear Analysis in Engineering Systems No.1(20), v10.

[2] Jones, C.L. (2003). Sound and Image Processing with Optical Biocomputers. 6th Engineering Mathematics and Applications Conference. Sydney, July 2003. http://arXiv.org/abs/nlin/0307007

[3] Altewischer, E., van Exter, M.P. and Woerdman, J.P. (2002). Plasmon-Assisted Quantum Entanglement. http://arXiv.org/quant-ph/0203057

[4] Fontana, E. (2004). Theoretical and Experimental Study of the Surface Plasmon Resonance Effect on a Recordable Compact Disk. Applied Optics. 43(1): 79-87.

[5] Koza, J.R. (2003). Human-Competitive Applications of Genetic Programming. Natural Computing Series . Advances in Evolutionary Computing: Theory and Applications. p. 663 - 682 Springer-Verlag, New York, NY, USA.

[6] www.swin.edu.au/maths/molecularmediaproject/molecularmedia.htm

[7] www.swin.edu.au/maths/molecularmediaproject/NID/nanotech4design.pdf

included mathematics and architecture, was firmly positioned as a core objective[8]. Our research builds upon and further develops the possibility of linking such disciplines; as such we also share our starting point by selecting Wassily Kandinsky's fundamental elements of form[9] as our first case study.

By selecting only three two-dimensional shapes and primary colours, our experiment was designed to determine the extent to which nanotechnology could be applied to perhaps the least complex of all design situations; with no formal brief, all resultant variants could be viewed and assessed subjectively on purely aesthetic grounds. Whilst it became apparent that a number of variants were reminiscent of more complex products such as toy like houses and boats, it is not our intention to suggest that nanotechnology would be utilized in such a manner by professional designers. More likely, a designer will have an absolute focus determined by a brief derived from client needs rather than rely upon nanotechnology to determine the nature of product to be designed; it is possible, however, that such findings could form the basis for further research related to the development of an educational software program for children.

If viewed as purely two-dimensional patterns, possibilities are also endless but more appropriate. For example the development of flags, stamps, logos is highly probable. It is also possible to imagine that certain variants could be used with no further input from the designer; whilst possible, it is more probable that the designer would be inspired to refine a small selection of variants. Further research could also include an exploration of the extent to which this process could be utilized in the development of typographical elements such as fonts and signs.

Case Study: Working With Students

Within the honors year of the Industrial Design program at the National Institute of Design, Swinburne University of Technology, students were asked to design furniture related to the workplace by deriving inspiration from previously manipulated images of furniture[10]. In this experiment, the manipulated images of furniture were taken from published catalogues of commercially available furniture and as such also provided an opportunity to review the value of creating a large database of images that could be potentially used as a generic inspirational tool; extensively questioning the development of an online static database. Approximately 50% of the students immediately applied themselves to developing furniture concepts inspired by the images; the resultant concepts were often far more experimental than their usual work though this could also be linked to my suggestion that students should attempt to divorce themselves from a need to provide solutions for manufacture; focus was placed instead upon blue-sky product development.

Whilst the remaining students found it difficult to develop concepts that extended upon their traditional modes of operandi, it is possible that given more time, familiarity with the process may have yielded a more positive result; If we accept that the nanotechnology approach to designing is in itself, a new cutting edge product, we must also accept a take up timeframe related to appealing, in the first instance, to more adventurous individuals prior to mainstream

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[8] Wingler, H,M. (1980). The Bauhaus. The MIT Press. Cambridge, Massachusetts, London. p. 75.
[9] Lupton, E. and Miller, J.A. (2000). The ABCs of Bauhaus, The Bauhaus and Design Theory. The Cooper Union for the Advancement of Science and Art, New York.
[10] www.swin.edu.au/maths/molecularmediaproject/NID/nanotech4design.pdf

adoption[11]. It is also possible that inspiration derived from manipulated images of pre-existing products rather than the individual students work does not create ownership and an emotional attachment to the product development process.

Case Study: Furniture Design

The third experiment involved one of the authors as a designer specializing in furniture design. Experimental furniture forms were designed and produced prior to this research[12]. Images were selected for manipulation with a view to determining the extent to which the resultant forms could either inspire the designer to further refine or provide stand-alone solutions that required only minor modification for manufacturing purposes. This was quite possible because the concepts were for a limited high cost production run negating any issues associated with mass production techniques, tolerances or materials. Following bio-nano manipulation, digital images of prototype furniture forms were returned to the designer and used as a catalyst to generate and refine further variations. This process was repeated until the designer determined that one of the resulting concepts had reached an appropriate stage of evolution. The concept was then detailed for production and prototype construction. The resultant furniture form physically embodies the decision making process employed by the designer derived from engaging in conversation (programming) with a molecular computer.

The experimental nature of the original furniture forms and the intention behind utilizing molecular computing was to further explore the possibility of relinquishing a certain amount of authorship[13]. In some respects, the brief was extremely open ended, perhaps more aligned with artists than designers; and perhaps for this reason, the experiment was extremely successful; not only as a catalyst for experimental furniture forms, but also as an aid to identifying the need for further case studies linked to more traditional contexts.

The Next Step: Electrolux and Braun

The first three experiments have provided evidence to support the potential for molecular computing to value add by playing a pivotal role within a design process; albeit within very specific contexts that are not necessarily in line with traditional commercial requirements. Primarily, for this reason, we will further test the process by working with designers from two of the worlds largest and most influential design teams specializing in mass production consumer products: Electrolux and Braun.

Electrolux recently opened an Australian office with a view to determining the nature and magnitude of specific cultural nuances that may aid in the development of more appropriate products.[14] Focus has been placed upon developing products that meet specific functional and aesthetic needs associated with open-plan kitchen/dining/living environments and indoor/outdoor living. Electrolux Designers will utilize molecular computing as an experiment with a view to determining its potential as a tool for use within the new product development process.

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[11] Tour, J.M. (2003). Commercialization of Molecular Electronics. Ch.1. Molecular Electronics – Commercial Insights, Chemistry, Devices, Architecture and Programming. World Scientific. p. 1-32

[12] Anderson, L. (2002). Enrichment: A Design Strategy Based Upon Observation, Unpublished PhD.

[13] Barthes, Roland. (1977). The Death of the Author: Image, Music, Text. New York: Hill.

[14] Stenning, B. (2003). Local Designers Influence Global Scene. In: Curve, Issue 2. p. 23-27.

Historically, Braun have had until recently one of the most formulaic product design processes; product branding derived from tight restraints related to proportion, form, colour and typefaces. More recently, Braun has experimented with product branding creating products with less 'Braun like' stylistic qualities.[15] New designers have joined the company with a view to further refining a new generation of Braun products. Two of these designers will experiment with molecular computing in much the same way as Electrolux.

Molecular Computing, Design and Ethics

Designers at Electrolux and Braun work within large product development teams, and typically access further information from specialist consultants, libraries and electronic sources. This is necessary as it is no-longer possible for individual designers to fully comprehend and single handedly design for complex production processes, ever changing cultural expectations and user needs. It is therefore inappropriate to suggest that concept development and new products are the work of a single author.[16] Vilem Flusser suggests that this process can lack moral responsibility which may lead to 'morally objectionable products' if there is disagreement in regard to the type of ethical code of practice adopted within the design industry.[17] It is clear that the development of molecular computing as a concept generating tool will further complicate and stimulate the debate about ownership and designer ethics[18].

Molecular computing can stimulate the development of alternate concepts, if the focus is purely one of developing aesthetic variants. To what extent, however, can it be utilized as a tool to create concepts that better meet societies needs? Is it possible for resultant products to embody superior ergonomic properties? For example, to be of use if designing for people with physical limitations, medical equipment, or for children?

Traditionally, a designer would respond by revising concepts in order to ensure that they would lead to cost effective solutions capable of being manufactured via prescriptive processes whilst refining the form with a view to increasing its functionality. Whilst society has far more regard and a greater understanding of ecological concerns and 3rd world conditions, a plethora of mass produced objects designed for the luxury market have secured Brand, Image and Status at the cost of function, ergonomics and sustainability.[19] To what extent then will molecular computing be utilized as a tool to perpetuate this market? It is of concern that non-professional designers could utilize molecular computing. This would surely lead to less resolved and potentially hazardous products. We point out though, that molecular computing offers similar results to those achieved using genetic programming[20], and that the latter has been actively used to

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[15] www.braun.com (20 April 2004).

[16] Anderson, L. (2003). Good Design. In: Inside Australian Design, Niche Media Pty, Melbourne. P. 55.

[17] Flusser, V (1999). The Shape of Things, A Philosophy of Industrial Design. Reaktion Books. London. p 66-69.

[18] Bainbridge, W.S. and Roco, M.C. (2001). Societal Implications of Nanoscience and Nanotechnology. NSET Workshop Report. Chapter 6.5. (p.188-253): Focus on Social, Ethical, Legal, International and National Security Implications.

[19] The Automotive Industry, Italian companies such as Kartell and Alessi, and a growing number of Japanese manufacturers pave the way in creating cult status symbolic products of little functional use.

[20] Koza, J. R., Keane, M. A., and Streeter, M. J. (2003). Evolving Inventions. Scientific American. Feb. 2003: p. 52-59.

reproduce patented designs[21] in an effort to automate the generation of new intellectual property. Another interesting question considers whether pattern matching over the sheer number of image variations might promote creative problem solving[22] and how cognitive insight[23] may be involved.

Molecular computing as a designer tool is in its infancy, yet the entire nanoscience discipline is expanding rapidly[24]. Therefore we can expect a rise in hybrid computing platforms that augment the computational process for creativity or performance. Some of our concerns will be answered relatively quickly whilst others will remain unresolved ultimately dependant upon the moral ground adopted by individuals rather than the profession.

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[21] Koza, J.R., Keane, M.A. and Streeter, M.J. (2003). What's AI Done for me Lately? Genetic Programming Human-Competitive Results. Intelligent Systems, IEEE. 18(3): 25-31.
[22] Badie, K. (2002). Creative Idea Generation via Interpretative Approach to Analogical Reasoning. Kybernetes. 31(9/10): 1210-1219.
[23] Beeman, M.J., Bowden, E.M., Haberman, J., Frymiare, J.L., Arambel-Liu, S., Greenblatt, R., Reber, P.J. and Kounios, J. (2004). Neural Activity When People Solve Verbal Problems with Insight. PLOS Biology. 2(4): 0500-0508.
[24] Braach-Maksvytis, V. (2002). Nanotechnology in Australia – Towards a National Initiative. Journal of Nanoparticle Research. 4: 1-7.