NATURE INSPIRED CREATIVE DESIGN – BRINGING TOGETHER IDEAS FROM NATURE, COMPUTER SCIENCE, ENGINEERING, ART, DESIGN

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ABSTRACT

This paper presents an account of the nature inspired design research network. It discusses the potential benefits of researching and adopting nature inspired approaches in design. It summarises the topics discussed in the network, which include evolution, growth and development, emergence and self organization, robustness, natural structures, and human design behaviour and performance; and it reports on the activities of and experiences with the network.

1. INTRODUCTION

Nature Inspired Creative Design [1] is a research cluster under the 'Designing for the 21st Century' program [2]. It is sponsored by the British Arts and Humanities Research Council and the Engineering and Physical Research Council. The network brings together people from a variety of disciplines to exchange ideas about art, design, nature and science. Its initial funding period was from April 2005 to the end of March 2006.

This paper presents the background and ideas of the network, predominatly from a computational view point. It also presents some of the result of the initial one-year funded phase of the network.

2. NATURE INSPIRED CREATIVE DESIGN

Nature is the ultimate designer. Every species, every individual, can be seen as the result of an implicit design process. At the same time, the results of this design process perform extremely well, in whatever measure of performance one might want to use. This even often includes aesthetic measures – there are many extremely beautiful species on Earth.

2.1 The Research Network

The main goal of this network is to explore what can be learned from nature for human design and engineering activities. However, this is not a one-way process. The nature of the funding puts an emphasis on applications to design, and this paper will maintain this emphasis. However, there is potential for transfer of ideas between all the groups participating in the network (Figure 1). Without this, the network would be one-sided and of questionable use to, perhaps, the majority of the members.

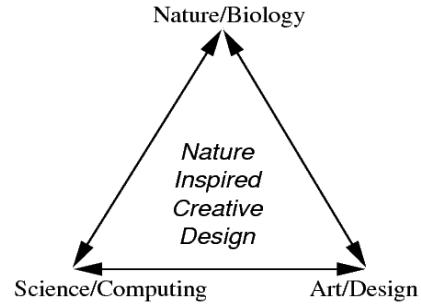

Figure 1: Nature Inspired Creative Design Network

2.2 Promises of Nature Inspired Design

By adopting nature inspired methods, we hope to solve some of the problems design currently faces. Nature inspired methods have a number of important potentials, as described in the following sections.

2.2.1 The potential to produce better designs

Comparing natural and artificial designs, it is clear that natural designs often have a number of advantages. For example, natural designs are usually:

- Resource efficient: Through continuous adaptation, natural designs have become parsimonious in their use of resources.
- Resilient to faults: Artificial designs often fail when individual components break. Natural designs, on the other hand, usually show graceful degradation: a small injury is usually not fatal to an animal, nor will the death of a number of individuals seriously endanger a colony of insects.
- Adaptable: Natural designs are usually able to adapt to the environment; sometimes this happens as part of the development process from genetic code to individual, sometimes this happens during the lifetime as physical change, or as behavioural change.
- Extremely varied: Natural design processes have produced individuals that span a massive range of scales, complexities, shapes and forms. Nature inspired processes can help designers to create very novel designs.

2.2.2 The potential to create better design processes

By taking inspiration from nature's methods, we hope to be able to find processes that are:

- More scalable: Nature has developed systems that show a very high complexity: human nervous systems, colonies of insects, large eco-

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systems are all examples. Very often, these systems are composed of a large number of elements with complex interactions. Designing artificial systems of similar complexity is often a very difficult process.

- More parallelisable: In natural evolution, there is no top-down design process – every species evolves on its own, and individual parts of a design (e.g. the beak of a Darwin Finch) can be optimised fairly much independently of other parts.
- More reliable: A very simple system consisting of 10 components interacting in 10 different ways has the state space of 10,000,000,000 possible states. A designer using conventional tools simply does not have the time to search the entire state space. Natural systems have developed various emergent methods for searching the state space of the system.
- More efficient: Natural design processes are unsupervised processes – no conscious designer is involved. Instead, processes of evolution, emergence, self-organisation and interaction with the environment determine the outcome. Together with the increasing availability of fast computer clusters, nature inspired approaches have the potential to provide efficient alternatives to labour-intensive manual design processes.

2.2.3 The potential to create better design tools

Nature inspired design tools have the potential to:

- Allow the user to search a larger design space: Designers are often limited to a small subset of the total design space, for a variety of reasons - lack of knowledge, lack of time, lack of design methods. Nature inspired methods may be able to help both in producing designs in a larger search space, and in evaluating these designs.
- Provide better support: Systems that know about the design process, and learn the user's preferences, will be able to provide better support to the designer. Nature inspired techniques can provide both languages to describe designs and learning algorithms.

2.2.4 The potential to provide knowledge about human perception and human creativity

Humans are a part of nature. They are also a result of an evolutionary process – our artistic perception and our creative abilities are formed by this process. By studying it, and by comparing human and computational creativity, we may be able to learn more about human creative processes.

3. Areas of Interest

With about 40 members from a variety of backgrounds actively participating in the network, there are nearly as many subjects discussed. The following sections attempt to categorise and summarise these subjects.

3.1 Evolution

The process of evolution has inspired a whole ecosystem of algorithms, generally referred to as Evolutionary Compution (EC) or Evolutionary Algorithms (EA). There is also an extensive body of work for EC in the art and design area, including this conference series. Most of this work is in the area of design optimisation. While there may be many technical challenges for any particular application, it is very straightforward to map the EC paradigm to design optimisation problems. Creative design and art using evolutionary algorithms (Evolutionary Art, Figure 2) has also been explored. The difficult issue here is generally finding a suitable fitness function, most often this is solved by 'human in the loop' approaches.

Evolution is probably the most prominent natural design process. As an unsupervised design process, with very successful results, it is an attractive idea. However, it is important not to forget that evolution on Earth has had more than 800 million years. Natural evolution is also extremely parallel: every individual in existence is essentially one fitness evaluation.

Representation and fitness, the two crucial parts of any evolutionary algorithm, has also featured in the network. The subject of suitable 'natural' fitness functions, particularly automated evaluation according to aesthetical criteria, has been one of the network topics (see also Section 3.6). Another topic of interest to the network is finding more natural representations for design (see also Section 3.3).

Co-evolution of different species can also provide a possible model of co-evolution between design and user preferences, and possibly be used to model user trends. Other, less explored uses of the principles of evolution are automated design in mass-customisation, and usage of evolutionary algorithms as explorative design aids.

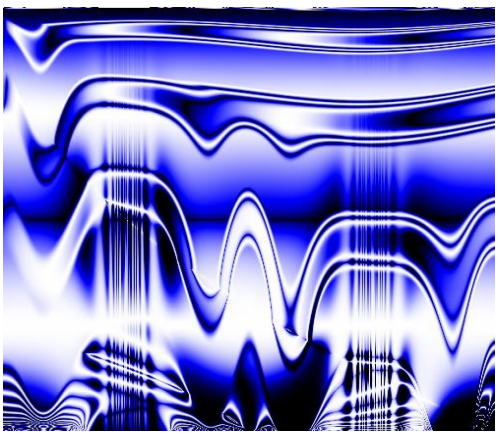

Figure 2: Example result of an evolutionary art program, (Thorsten Schnier and Kennon Ballou)

3.2 Self Organisation and Emergence

Emergence is generally the result of the interaction of a large number of individual entities. Both emergent

behaviours (e.g. sorting behaviours of ants) and emergent structures (e.g. patterns on sea shells) can be observed in nature. Emergent phenomena are generally very robust, for example sorting ants will still be able to sort if half of them are killed, or if obstacles are placed in their way. Emergent phenomena such as these also mainly rely on local, one-to-one communication, and are therefore generally very scalable.

Systems displaying emergent behaviours can often be simulated on computers. This includes models of human behaviours, for example evacuation of crowds from buildings. Design of emergent systems is more difficult. Because of the non-linear interactions, it is often very difficult to predict and engineer emergent behaviours and structures. Evolution (and EC) may be one of the best mechanisms available.

Self organisation is a related phenomenon, in which higher-level order arises from the interaction of lower-level parts. Self organisation and emergence may suggest methods of teamwork in humans. Finally, self organisation can also be used in art, as explored by one network member (Figure 3).

Figure 3: Self Organization using Paint (Gail Troth, Picture used with permission)

3.3 Development and Growth

Development is the process that transforms a set of genetic information (genoype) into an individual (phenotype). Biological development, especially in higher-order species, is a highly complex multi-level process. Nevertheless it can be extremely robust – for example, faults in the process (any kind of small birth defects) can still lead to viable individuals. Environment plays a strong role – the process can be robust to some environmental changes, but other environmental factors may be highly critical (e.g. egg temperature). It can also take advantage of and adapt to the environment; for example bone growth depends on the loads on the bone.

There is interest from the biological side in the dynamics and robustness of development, but there is also a very strong interest from the evolutionary computing community. Conventional evolutionary computation uses very direct genotype-phenotype transformations. EC researchers are very interested in reprensentations that involve a development process, and result in robust processes which can be influenced by the environment (using for example evolvable hardware). An interesting question is also how indirect, growth and development based representations change the evolutionary dynamics – do they make it easier or harder to evolve complex phenotypes? Potential models include reaction-diffusion systems and chaos/attractor based models.

3.4 Robustness

Robustness is a design quality that is abundant in natural design, but often very difficult to achieve with conventional design processes. Robustness issues have already been explored in the previous two sections. However, there are other mechanisms that nature uses to achieve robustness. One mechanism explored by the network is the combination of compliant (flexible) structures with active control.

3.5 Existing Structures in Nature

The previous sections all discussed processes in nature that are interesting from the design point of view. Another source of inspiration for art and design are the structures employed by nature. The growing field of Biomimetics is concerned with identifying particular design solutions in nature, and converting them into usable artefacts – essentially 'stealing' ideas from nature. Nature has also of course been used for a very long time in art, design and especially architecture to inspire patterns, structures, and shapes.

3.6 Humans and Design

Humans are also part of nature, and we can learn a lot about design by looking at 'natural' human design processes.

One example is our sense of aesthetics. In order to create an artificial aesthetics measure, we need to understand the nature of the human sense of aesthetics. Individual development and experience plays a role, but some of it appears to be innate. One of the research projects coming out of the network is interested in the evolutionary origins of aesthetics. Understanding this will not only increase our understanding of humans, but may also provide important hints in how to design artificial selection methods for aesthetics. Related to this is the 'sense of play' in individuals, as well as the tacit knowledge involved in actually making things.

Another interesting aspect is the difference in human reaction to natual and artificial objects, what features make an object appear 'natural', and how this can influence the design process.

Another subject of interest is ambient art. Here, art and artistic methods are used to present elements of information from the environment in some way to the user. The research aims to explore the role of ambient art as both a new approach to artistic expression, and in understanding the process of creating it which

allows us to transfer knowledge from the artistic domain into more technical and scientific domains.

The network is also interested in the influence of human design on nature, including ethical questions about, for example, the ethics of manipulating animal genes and development for artistic purposes.

4. The Network

The initial AHRC/EPSRC funded network period was from 1st April 2005 to 31st March 2006. Throughout this time, we have had very positive reactions to the interests and goals of the network, both from network members and from members of the public, through the web site and public presentations. There appears to be a large community of people interested in the broad subject, from all disciplines represented in the network. The growing mailing-list membership, and the success of the workshops, also attest to this.

The network will continue to run for the forseeable future, based on the website and mailing list, with meetings once or twice annually. A network exhibition is planned for summer 2006. We also hope to develop the network into a more formal forum in the long run.

4.1 Network Membership

During the one-year funded period of the network, it has grown from an initial membership of around 20 to about 40 active members. The mailing list continues to grow, and at the time of writing contains more than 90 members. The network membership comprises artists, designers, design scientists, biologists, engineers, and computer scientists. Active members come from all over the UK, while some of the mailing list members are in other countries.

4.2 Network Meetings

During 2005, the network organised three successful meetings, each one generating a lot of lively discussion, debate and new ideas. Meetings included presentations from members as well as demonstrations of work, ideas and experiments, and we also had some nature-inspired art on display. At all three meetings we had a good cross-section of attendees representing diverse disciplines and viewpoints. This cross-fertilisation of ideas is at the heart of our aims and activities, and will drive the research proposals and future initiatives coming out of the network.

4.3 Online Resources

The network has its own website at www.nature-inspired.org. This website is used to distribute information about network events, collect resources and advertise the network. It is set up as a collaborative resource using *wiki* technology, which allows all registered members to add material.

5. Outcomes

5.1 Proposals

At the time of writing, network members are discussing a number of proposals to the next funding period. Thirteen topics were identified in the third network meeting [3]. The following three proprosals are likely to go ahead:

- Growth and Development based on Biological Models
- The Evolutionary Advantage of Aesthetics
- An Evolutionary Sculpture – Dynamic, Interactive, Evolving.

5.2 Network Dynamics

The network showed an interesting split in the commitment and contributions it elicited. On one side, the network meetings have succeeded extremely well in engaging the network members. On the other hand, it has been very difficult to get contributions from network members between the meetings. The collaborative potential of the website has not been widely used, and only a small number of members have contributed to meeting preparations and mailing list discussions. One reason for this was undoubtedly the density of events in the 'Designing for the 21st Century' cluster, with 21 networks holding meetings, and a large overlap in cluster membership.

6. Summary

There is a large potential for nature inspired ideas in a range of design activities. This network has been very successful in bringing together a group of interested professionals from diverse fields. While it has generated many ideas, it has as yet only scratched the surface of the possibilities. It remains for future network activities and research partnerships to explore these ideas further.

Thanks

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