DNA in nonliving systems

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Is my tooth brush made out of DNA? Is my printer made out of DNA? Is my microwave made out of DNA? My "impression" was that DNA was the unit of heredity which makes up "living things". So what am I to make when I read, "All evolutionary systems employ a language in the specification of the design of either a living or nonliving system. This specification is called DNA, in parallel to the biological analog."
This suggests the evolutionary system of nonliving systems employs the language DNA. It goes on to say, "In natural biological systems, the representation is naturally compartmentalized." The researchers, however, are currently investigating the limitations of non−compartmentalized models of evolution. Soon, we will investigate possible extensions of non−compartmentalized models to compartmentalized models of evolution."

Is this somekind of theoretical mathematical game. How can DNA be the design of a nonliving system? I've heard of DNA computers. What is the definition of life here?

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Compartmentalization in Evolution

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Humankind currently enjoys the benefits of a great deal of technology.

This technology has been built up by our capability to understand how things work and to manipulate parts of our real world. Historically technology of two general types has been used in the generation of new and exciting improvements in human capabilities. The first type consists of those objects which have been used for a purpose other than that originally intended. These include leaves used as roofing material, cotton used as clothing, ropes fabricated from leaves, etc. Although primitive in many respects, this technology is still in use today, and its use will likely continue for some time. The second type of technology is made up of devices, substances, and processes which have been fabricated, using a complete understanding of the underlying scientific processes. From petroleum, people have created a number of synthetic substances, including very strong plastics, and synthetic fabrics. From metals, people have created very strong and very light substances, with metallurgy improving as our understanding of the structure and chemistry of metals improved. Most recently, microfabrication techniques and understanding of quantum effects has effected our ability to create very small machines and devices, generating our recent revolution in information technology. Recently, the complexity of systems requiring human understanding has become daunting, even for the most adept scientist or engineer. This has necessitated the creation of computer aided design programs, allowing the typical engineer to create and test designs with greater ease and accuracy than ever before. However, despite the improvements, the designs still require the engineer to be able to understand the device as a combination of separated devices, rather than a complete whole. Understanding the device not as a collection of separate devices but rather as a whole device requires the development of techniques that allow one to understand complex devices. Moreover, optimization of such devices requires the simultaneous alteration of many devices at once, which cannot be done by the typical engineer in a small amount of time. In order to deal with these problems, a new set of algorithms has been developed and is in development. These algorithms are known as evolutionary algorithms . Evolutionary algorithms are designed to make small modifications to a given design and to rank the improvement against the previous design. Typically, many iterations of such small improvements and rankings, strung together, will produce a final optimal design.

All evolutionary systems employ a language in the specification of the design of either a living or nonliving system. This specification is called DNA, in parallel to the biological analog.Typically, it is represented as a list of commands designed to provide information on how to build the system. These commands are represented as a string of commands, and interpreted by the system building the device. As it turns out, the representation of the DNA is a critical issue in the generation of quick evolutionary strategies. Improper representations can lead to epistasis or stagnation in the evolutionary systems. In natural biological systems, the representation is naturally compartmentalized. This allows bits of DNA encoding specific tasks to be duplicated and modified without damaging the functionality of the other DNA, and allowing exploration of design space without destruction of the design or organism. This is accomplished in part by using transposons and genes. That these structures are ubiquitous is of interest because it indicates that there might be a fundamental reason for the success of such systems. Our research indicates that there is a fundamental reason for the dominance of transposon−based systems. This would seem to be a mathematical property of evolutionary systems, and point to an important design constraint for evolutionary design systems. We are currently investigating the limitations of non−compartmentalized models of evolution. Soon, we will investigate possible extensions of non−compartmentalized models to compartmentalized models of evolution.

Publications

S. Kazadi, M. Lee, L. Lee A Case for Exhaustive Optimization Proceedings of Gecco 2005 Conference, Late Breaking Papers , Washington D.C., USA, June 2005. (Postscript) (PDF)

Abstract

Evolutionary algorithms have enjoyed a great success in a variety of different fields ranging from numerical optimization to general creative design. However, to date, the question of why this success is possible has never been adequately determined. In this paper, we examine two algorithms, a genetic algorithm and a pseudo−exhaustive search algorithm dubbed Directed Exhaustive Search. We examine the GA's apparent ability to compound individual mutations, and its role in the GA's optimization. We then explore the use of the DES algorithm using a suitably altered mutation operator mimicking the GA's surreptitious compounding of the mutation operator. We find that the DES algorithm is capable of performing comparably to or outperforming the GA over all test problems, as predicted by theory.

S. Kazadi, D. Johnson, J. Melendez, B, Goo. Exhaustive Directed Search. Proceedings of the Genetic and Evolutionary Computation Conference, 2004 , Seattle, WA, USA, 2004. (postscript) (PDF)

Abstract

We explore the development of an exhaustive directed search of state space based on concepts from evolutionary computation. A brief investigation of the evolvability of an evolutionary algorithm illustrates that evolutionary algorithms are capable of reaching optimal solutions when the diversification operator (which may be a

pseudo−operator which acts over many different diversification steps) is capable of reaching, at every improvement point, another, more improved population element. Moreover, we demonstrate that the upper limit on the time to the optimal point is identical to that of an exhaustive directed search. This search is exhaustive, but borrows the diversification operator from the evolutionary algorithm and proceeds in such a way that, if left alone, it would exhaustively search the space. However, we demonstrate that this type of search can perform comparably with the evolutionary algorithm, avoiding deceptive search tracks that might trap an evolutionary algorithm.

S. Kazadi, D. Choi, A. Chang, T. Kang, H. Li, D. Kim, S. Ho, J. Wu. On the Design of an Evolutionary Preprocessor. Proceedings of the Genetic and Evolutionary Computation Conference, 2003 , Chicago, IL, USA, 2003. (postscript) (PDF)

Abstract
In this paper we explore methods of enhancing the evolvability of a particular device. We assume that the device may be specified by a table of inputs and outputs. We investigate a method of extracting the topologial structure of the device from rarified absolute Hessian matrices (raH matrices) and using this topological information as the basis for construction of solutions to evolutionary problems. We validate the algorithm by demonstrating its ability to extract the structure of devices to be evolved from the input/output table. Moreover, we validate this structure by using a genetic algorithm to train a perceptron, yielding perceptrons which solve the computational problem with error rates of less than 4\%.

S. Kazadi, S. Cheung, C. Ogletree, S. Kim, C. Lee, A. Min. A Study of Evolutionary Acceleration. Proceedings of the Genetic and Evolutionary Computation Conference, 2003 , Chicago, IL, USA, 2003. (postscript) (PDF)

Abstract
We investigate the phenomenon of numerical evolutionary acceleration. This phenomenon is a simple consequence of numerical analysis of the probabilities of evolving independent parts of a complex system in the presence of evolutionary epochs. The epoch mechanism allows the newly evolved structure to become part of the overall system design of all elements of the population. We demonstrated that this phenomenon not only exists in real evolving systems, but that evolutionary acceleration dwarfs the group mechanism for some complex structures.

S. Kazadi, Y. Qi, I. Park, N. Huang, P. Hwu, B. Kw an, W. Lue, and H. Li. Insufficiency of Piecewise Evolution. Proceedings of the Third NASA/DoD Workshop on Evolvable Hardware , Long Beach, CA, 2001. (postscript) (PDF)

Abstract
We describe an evolutionary design paradigm called piecewise evolution ... This evolutionary design paradigm allows the gradual evolution of a piece of hardware using discrete functional stages. The paradigm removes designs from a population of designs which effectively lose functionality already discovered. Significant improvements in the evolution time of simple one−bit adders are reported. However, evolution of more complex devices does not seem to share the improvements in evolutionary speed of simple devices. These results are discussed in the context of epistasis and deceptiveness.

S. Kazadi, D. Lee, R. Modi, J. Sy, W. Lue. Levels of Compartmentalization in Artificial Evolution. Proceedings of GECCO 2000 , pp.841−849, 2000. (postscript) (PDF)

Abstract
This paper addresses the use of particular encoding schemes in evolutionary systems. We define three paradigms of DNA encodings: non−compartmentalized DNA , partially compartmentalized DNA, and fully compartmentalized DNA. We demonstrate that there is a significant and increasing advantage to the use of partially and fully compartmentalized models as the complexity of a structure increases. Implications for the design of evolutionary systems including biological systems are discussed.

S. Kazadi, D. Lee, R. Modi, J. Sy, W. Lue. Levels of Compartmentalization in Artificial Life. Proceedings of Artificial Life VII , Bedau, McCaskill, Packard, and Rasmussen, eds.: MIT Press, 81−89, 2000. (postscript) (PDF)

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