Evolutionary Design by Computers

Edited by Peter J. Bentley

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This book on evolutionary design by computers, edited by P. Bentley, is a perfect follow-up to López de Mántaras’s editorial on Artificial Creativity (López, 99), in which he discusses the role of the computer in human creativity. Starting with Dawkins’ book on Darwinian theories (Dawkins, 96), in which natural selection is explained using computer simulations, numerous researchers have taken inspiration from the evolutionary process to implement novel searching and optimization techniques based on genetic algorithms. Peter J. Bentley is one of these, having opened up a new line of research in which evolutionary techniques are applied to design. He takes design to have a wide meaning; from the optimization of system parameters to the complete creation of objects, mechanisms, or processes, encompassing both conceptual and esthetic design.

In this volume, Bentley gathers together 18 original works by 33 authors on diverse aspects of evolutionary computing applied to design. The book does an excellent job of providing an overall view of the current state of research in the area, and of bringing together the various lines of research in evolutionary algorithms (genetic algorithms, genetic programming, etc.) in the generic design process.

The first contribution, by the editor himself, serves as an introduction to the field. The author makes a convincing argument for the use of evolutionary techniques for design. 1) Evolution has been able to solve numerous diverse problems with a common theme. 2) Evolutionary algorithms have been used successfully in all types of evolutionary design. 3) Evolution and the human design process have many common features. 4) The designs which humans find most remarkable were created by natural evolution, the source of inspiration for evolutionary algorithms. The article discusses the main areas of research and the problems of evolutionary algorithms (i.e. genetic algorithms and genetic programming) which invite more investigation in the medium term.

Bentley reviews the roots of evolutionary design, springing from the intersection between computer science, design and evolutionary biology. He divides Evolutionary Design into four branches of research; evolutionary optimization of designs, creative evolutionary design, conceptual evolutionary design, and evolutionary art.

A summary and review of the most significant articles in each section follows.

Evolution and Design

The first section contains four articles related to the role of evolution and design. The authors view design from an evolutionary point of view, discussing basic concepts, strategies, criteria and general points of view on evolution, existing computational evolutionary techniques, and design.
Most notable is the contribution of D. Goldberg, who treats the problem of automating the innovative and creative process of design. Goldberg maintains that continuous improvement of a design can be the result of selection and genetic mutation, while innovation can come out of selection and genetic recombination.

The contributions in this section serve to establish the theoretic and practical bases of the role that evolutionary algorithms can play in the design process.

**Evolutionary Optimization of Designs**

The second section contains three papers on optimization of designs using evolutionary techniques. This field is better known as genetic algorithms. These algorithms are used to converge on an optimal solution in the search space of critical variables in a traditional design. The authors of the three papers treat, respectively,

- mechanical design to minimize vibrations and structural tension,
- the shape of rotating disks to store kinetic energy, and
- design of data networks to maximize reliability.

**Evolutionary Art**

This is an area with considerable potential for the use of evolutionary computational techniques. In this section, made up of three contributions, arbitrary artistic forms are codified freely in the genotype. The artist then acts as an aptitude evaluation function, artificially selecting a genetic algorithm. Genetic recombination of esthetic designs gives the artist the creative possibility to explore and choose the phenotype most suited to the creative concept he has imagined (Holtzman, 1994). Evolutionary techniques have been applied successfully to forms, textures, sounds, and music, among others.

In this section, a notable contribution is that of S. Todd and W. Latham on Mutation and Growth of Computer Art, in which they formulate a grammar of shapes and mutation and growth operations to modify them, producing some esthetically interesting results.

In his article on Evolutionary Art and Form, A. Rowbottom surveys the various academic and commercial packages for evolutionary art. The range of software reviewed gives an idea of the wide gamut of possibilities in esthetic creation, most notably commercial applications for the creation of new textures in infographics and virtual reality.

**Evolutionary Forms of Artificial Life**

The three papers in this section explore various aspects of Artificial Life, one of the leading edges of Artificial Intelligence, and another area which uses evolutionary techniques. The first paper describes part of the work of H. de Garis in Artificial Embryology. In this area, designs are created starting with basic units analogous to cells, which are then assembled according to the indicated genotype.

Another contributor, K. Sims, writes on Evolution of 3D Morphologies and their Behavior, in which he creates creatures using basic blocks, whose movement and behavior is generated by an evolutionary process.

**Creativity in Evolutionary Design**

The last section contains four works on creativity in evolutionary design. The authors treat the problem of creating complex designs starting from nothing, without necessarily having any information either about the genetic coding or about the final objectives of the design. This section is the most appealing part of the book, due to the potential of this field for application of evolutionary algorithms to any type of design. The contribution of J. Gero and M. Rosenman shows how representations of an object in a genotype can be transformed through evolution, and how hierarchical structures can be put together to tackle the problem of complex designs.

J. Koza, a well-known researcher in genetic programming, describes the design of analogue circuits using genetic programming. Circuits generated by an evolutionary process range from passive analogue filters to models with transistors, including an amplifier.

The article by J. Pollack presents the evolutionary design of model cranes and blocks constructed from LEGO™ blocks.

The book concludes with another piece by P. Bentley, in which he presents the results of his research in the area. He discusses his generic evolutionary design system GADES (Genetic Algorithm Designer), which has provided impressive results in both the design of solid models of cars, trains and tables, and in the design of the distribution of rooms on a hospital floor.

**The CD-ROM**

The book includes a CD-ROM with HTML interface, which allows catalogued access to the areas covered in the book. It also includes P. Bentley’s PhD thesis on Evolutionary Design of Solid Objects Using Genetic Algorithms, and the source code of his generic evolutionary design system GADES as presented in the final article of the book.

The CD-ROM also includes various software packages and further information gathered directly by the authors, including links to documents, code, and reference materials included in the disk and at other Internet sites. The CD-ROM unites in one medium material which will be invaluable for the
researcher who wishes to go deeper into any aspect of evolutionary design, or who seeks simply to apply concepts presented in other areas of CAD research.

Conclusions

This book is highly recommended not only as a first book in evolutionary design, but also as an introduction to computational evolutionary techniques (such as genetic algorithms). The authors provide an excellent bibliography, and discuss the principal lines and future trends of research in the medium to long term.

Human creativity added to evolutionary design will suggest many new applications, in which evolutionary design will allow exploitation to the fullest of technical, esthetic and functional possibilities offered by modern manufacturing technologies. Evolutionary design provides new opportunities for the development of interfaces, of methodologies, of tools which further designers' creativity, and of traditional creative computer activities, among others. Moreover, the application of evolutionary design to creative tasks can stimulate new ideas in industrial design and can benefit the nation by the creation of new products and systems in which the added value stems from the addition of the intellectual-design task to manufacturing.

References


Holtzman, S. Digital Mantras. The Languages of Abstract and Virtual Worlds. MIT Press. 1994