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GUEST EDITORIAL

Special Issue: Evolutionary Design

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Throughout the natural world and our human-designed world, design and evolution seem to go hand-in-hand. Some of the most astonishing and complex designs known to humankind—the embryogeny process, the immune system, the brain, the very structure of DNA—are products of natural evolution, not human endeavor. In addition, the progress of our own designs seems evolutionary, as the best concepts from existing designs are combined with some small variation to produce the next generation of cars, computers, and indeed, most types of human design. And now, as the papers in this and subsequent special issues will show, our computers are allowing us to harness the power of evolution directly, to aid the design process.

It is the rapidly expanding field of Evolutionary Computation that has triggered these promising new approaches for design problems. Inspired by the mechanisms of natural evolution, the algorithms that comprise evolutionary computation seem to be almost unrivaled in their abilities as general-purpose search techniques.

An evolutionary algorithm searches a solution space in parallel. Populations of solutions are maintained, these solutions are evaluated, and the best or fittest in the population are selected as parents. The parent solutions then reproduce, resulting in a new generation of solutions that inherit their characteristics from their parents, with some small random variation. The new solutions are evaluated, the fittest are picked as parents, and so on. This simple process causes evolution to occur, with the solutions becoming fitter (and better able to solve the problem) every generation.

Over the last 10 to 15 years, the use of evolutionary algorithms for design problems has grown exponentially. Design centers all over the world have recognized the value of evolution for solving complex and difficult tasks. As my recent book *Evolutionary Design by Computers* describes, these techniques are being used successfully for a long list of applications, including satellite booms, load cells, flywheels, computer networks, artistic images, sculptures, virtual creatures, architectural plans, bridges, cranes, analogue circuits, and even coffee tables.

The genetic algorithm (GA) is perhaps the most widely used evolutionary algorithm for design problems, and the three papers that comprise this partial special issue describe three different approaches using a GA. The first paper, *A Voxel Based Representation for Evolutionary Shape Optimization*, by Peter Baron, Robert Fisher, Andrew Tuson, Frank Mill and Andrew Sherlock, provides an investigation of a key area in evolutionary design—the representation. The paper provides an examination of a voxel representation and demonstrates how it can be used usefully for structural design problems. This interesting work also explains how additional knowledge about the problem can be used to improve designs evolved with a GA using this type of representation.

For practical evolutionary optimization systems, it is vital to reduce the amount of time taken up evaluating solutions. The second paper, *Learning to be Selective in Genetic-Algorithm-based Design Optimization*, by Khaled Rasheed and Haym Hirsch, concentrates on this area to improve the performance of evolutionary optimizers for difficult design problems. This excellent paper introduces a new approach to ensure that the GA does not waste time exploring areas of the search space which seem to be lacking good solutions. It also confines the search of the GA to areas of the search space that contain feasible solutions that can be evaluated.

Researchers are beginning increasingly to concentrate their efforts on embryogeny or growth processes within evolutionary design systems. This important idea set looks to transform the way we perform evolutionary design. By evolving a set of "growing instructions," which define how designs should develop, a small genotype can define a vastly more complex phenotype, and constraint handling can be taken care of without adversely affecting evolution. The third paper, *Adaptive-Growth-Type 3D Representation for Configuration Design*, by Toshiharu Taura and Ichiro Nagasaka, presents a novel way of achieving this. The paper describes an evolutionary design system that defines morphology by the density of "cells" growing on parts of a sphere. Rather than directly generate the shape, evolution is used to help determine where and how the "cells" are placed on the sphere. This original approach illustrates the important notion of representations that can adapt to changes in environment and constraints.

These three papers, and the papers to follow in the subsequent special issues, show the diversity and potential of the young field of evolutionary design. Current research in evolving embryology, reducing the time taken to evaluate solutions, and incorporating knowledge into the evolutionary process will further increase the usefulness of these techniques for the myriad of applications emerging from industry.