

Generic Evolutionary Design of Solid Objects using a Genetic Algorithm

A thesis submitted to the University of Huddersfield
in partial fulfilment of the requirements for the degree of
Doctor of Philosophy.

By
Peter John Bentley B.Sc. (Hons)
November 1996

Division of Computing and Control Systems
School of Engineering
The University of Huddersfield

Abstract

This thesis investigates the novel idea of using a computer to create and optimise conceptual designs of a range of differently-shaped three-dimensional solid objects from scratch. An extensive literature review evaluates all related areas of research and reveals that no such system exists. The development of a generic evolutionary design system, using a genetic algorithm (GA) as its core, is then presented.

The thesis describes a number of significant advances necessitated by the development of this system. Firstly, a new low-parameter spatial-partitioning representation of solid objects is introduced, which allows a wide range of solid objects to be appropriately defined and easily manipulated by a GA. Secondly, multiobjective optimisation is investigated to allow users to define design problems without fine-tuning large numbers of weights. As a result of this, the new concepts of acceptability, range-independence and importance are introduced and a new multiobjective ranking method is identified as being most appropriate. Thirdly, variable-length chromosomes in GAs are addressed, to allow the number of primitive shapes that define a design to be variable. This problem is overcome by the use of a new hierarchical crossover operator, which uses the new concept of a semantic hierarchy to reference chromosomes.

Additionally, the thesis describes how the performance of the GA is improved by using an explicit mapping stage between genotypes and phenotypes, steady-state reproduction with preferential selection, and a new lifespan limiter. A library of modular evaluation software is also presented, which allows a user to define new design problems quickly and easily by picking combinations of modules to guide the evolution of designs.

Finally, the feasibility of the generic evolutionary design of solid objects is demonstrated by presenting the successful evolution of both conventional and unconventional designs for fifteen different solid-object design tasks, e.g. tables, heatsinks, penta-prisms, boat hulls, aerodynamic cars.

Acknowledgements

I would like to thank the following people:

John Bullingham and Mike Thorn for agreeing to let me turn my ideas into a reality.

My supervisor, Jonathan Wakefield for his enthusiasm, his constructive advice, and his excellent abilities as a proof-reader.

Dave Goldberg for providing me with huge numbers of his research papers and some useful contacts.

Dave Schaffer for providing his support (and his test functions) for my work on multiobjective optimisation.

William Latham for his interest in this work and his permission to reproduce one of his pieces of Evolved Art in this thesis.

Karl Sims for his inspirational presentations and papers, and his permission to reproduce images of his evolved competing creatures in this thesis.

Richard Dawkins for his permission to reproduce images of his evolved 'biomorphs'.

The many interested readers of my research papers for some stimulating discussions at conferences, workshops and over the internet.

My friends and family for welcome distractions and their continuous unwavering support.

And finally I would like to thank the cruel and indifferent, yet astonishingly creative process of Natural Evolution for providing the inspiration for my work. Long may it continue to do so.

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