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Evolvable Hardware

Genetic and Evolutionary Computation Series

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Evolvable Hardware

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PREFACE

Evolvable hardware refers to hardware that can learn and adapt autonomously in a dynamic environment. It is often an integration of evolutionary computation and programmable hardware devices. The objective of evolvable hardware is the autonomous reconfiguration of hardware structure in order to improve performance over time. The capacity for autonomous reconfiguration with evolvable hardware makes it fundamentally different from conventional hardware, where it is almost impossible to change the hardware's function and architecture once it is manufactured. While programmable hardware devices, such as a PLD (Programmable Logic Device) and a FPGA (Field Programmable Gate Array), allow for some functional changes after being installed on a print circuit board, such changes cannot be executed without the intervention of human designers (i.e., the change is not autonomous). With the use of evolutionary computation, however, evolvable hardware has the capability of autonomously changing its hardware architectures and functions.

The origins of evolvable hardware can be traced back to Mange's work and Higuchi's work, which were conducted independently around 1992. While Mange's work has led to bio-inspired machines that aim at self-reproduction or self-repair of the original hardware structure rather than evolving new structures, Higuchi's work has led to evolvable hardware research utilizing evolutionary algorithms for the autonomous reconfiguration of hardware structures. This book focuses primarily on the second line of research.

Departing from the initial interest of the artificial intelligence and artificial life communities in evolvable hardware to autonomously evolve hardware structures, recent evolvable hardware research has come to address some important topics for semiconductor engineering and mechanical engineering, such as:

- post-fabrication LSI adjustment,
- LSI tolerance to temperature change,
- self-testing/self-repairing LSI,
- human-competitive analog design,
- MEMS fine-tuning,
- adaptive optical control with micron-order precision, and
- evolvable antenna for space missions.

Research activities relating to evolvable hardware are mainly reported at two international conferences. The first one is the series of International Conferences on Evolvable Systems (ICES). The second is the NASA-DoD Evolvable Hardware Conferences that have been held every year in the USA since 1999. While it is rather difficult to neatly classify this body of research activities, this book adopts the following three categories:

1. Digital hardware evolution
 - (1-1) Digital evolvable hardware based on genetic algorithms
 - (1-2) Bio-inspired machines
2. Analog hardware evolution
 - (2-1) Analog evolvable hardware based on genetic algorithms
 - (2-2) Analog circuit design with evolutionary computation
3. Mechanical hardware evolution

This book brings together 11 examples of cutting-edge research and applications under these categories, placing particular emphasis on their practical usefulness.

Tetsuya Higuchi
Yong Liu
Xin Yao

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