Title:	Hardware evolution: automatic design of electronic circuits in reconfigurable hardware by artificial evolution.
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This book is an insightful and entertaining story of how you can automatically design hardware using evolution, and why you should want to. Originally written as Thompson's doctoral thesis, it has been reproduced as part of the Distinguished Dissertation Series of the best of British doctoral theses. Thompson is now a recognised expert in the field of evolvable hardware, and this book describes the research that elevated him to this position, including his seminal experiments investigating the benefits of evolving hardware.

To be selected for this series of books, a thesis should allow a computer scientist unfamiliar with the field to grasp its essentials. This is true here but remarkably, even to understand the finer details, the reader need only have a passing knowledge of evolutionary computation and circuit design. Reproduced unaltered, it is a good example of a well-structured thesis. This means it is not suitable for reference or for use as a textbook.

Thompson introduces the work by describing reconfigurable hardware - chips that permit their constituent resources and connections to be altered by software - and how an evolutionary algorithm can evolve circuits by evaluating successive configurations downloaded onto these chips. Following this, he lays out the research hypotheses that the book addresses, just as a thesis should. The first are specific to hardware evolution, and suppose that evolution can explore beyond the realms of conventional circuit design, finding better solutions that conventional design methodologies in the process. This is the main message of the book, but he also sets out a loosely related hypothesis suggesting that evolutionary algorithms can be set up to provide engineering benefits for free. He ties this to the theme of hardware evolution by using an example of fault tolerant hardware.

A chapter is devoted to setting the research in the context of other work in the fields of evolvable hardware, VLSI design, evolutionary computation and computer science. In 1996 when the thesis was submitted, this was a good review of current evolvable hardware research. The field has progressed in the intervening years, and this chapter now only serves to portray Thompson's inspirations. It makes an interesting historical read nonetheless.

The meat of the book is Thompson's description of a series of elegant experiments exploring his hypotheses. The main theme of these is that evolution is allowed to search a circuit design space where conventional spatial and dynamical design constraints, such as modular design and clocked feedback of combinational logic, have been relaxed. After showing that circuits can be evolved in such spaces, Thompson presents another experiment where a circuit to solve a real design problem - a wall-avoiding robot controller - is evolved under similar conditions. He uses this to show that the rich dynamics that can arise through unconstrained hardware evolution can be useful. Throughout his account of the experiment he stresses that unconstrained hardware evolution can produce circuits better adapted to the physical medium of the chip than conventional design would allow. He points out that this can be particularly useful when a circuit needs to interact directly with the real-time dynamical systems we find in the physical world. His concluding point is that constraints that are copied from natural systems just because they work well with natural media can limit hardware evolution in the same way as constraints copied from traditional circuit design.

Chapter five describes what is to date the most striking (and widely cited) demonstration of the principles discussed throughout the book. A circuit is evolved to distinguish between signals of two frequencies. This experiment not only re-enforces Thompson's arguments, but displays the engineering potential of his work more clearly than ever. Again, the circuit is evolved on conventional digital reconfigurable hardware with relaxation of the temporal and physical constraints used by human designers. His brief analysis of the evolved circuit does enough to show that the circuit is working in a very unusual way, perhaps by using the power supply lines, or electromagnetic coupling. You may find that the lack of firm conclusions in this respect whets your appetite for a more thorough analysis. If so, consider exploring some of Thompson's more recent work [4].

Finally Thompson discusses what at the time of submission were plans for future work, most of which has now been carried out both by his own group [3,5] and others [1,2]. The discussion concentrates on evolved hardware's sensitivity to changes in environmental conditions. Thompson notes that for his techniques to be of engineering value this issue must be addressed, and proposes possible solutions along with early results. Areas of application are also briefly discussed. Thompson concludes by re-iterating each of his hypotheses along with a summary of the evidence presented earlier to support them.

Throughout the book, Thompson's arguments are well structured and clearly written. Although he raises many interesting issues, such as evolvability (in particular neutral network theory), and the benefits of developmental processes and embryonic architectures, he keeps the story lean and does not dwell on peripheral questions. As a result, the book is very readable. However much of the scientific content of the thesis has been published in papers available on Thompson's web site [6]. In addition, although the work was seminal, it has been outdated by the more recent work of Thompson and others. This book is not a text on the state of the art. If you want to learn how to conduct and present research, or if you are taking your first steps into the field of evolvable hardware, then it is a must. If you are looking for a fascinating story, you could do worse. As such, it would make a fine addition to any computer science library.

1. Masner J., Cavalieri J., Frenzel J. and Foster J. (1999), Representation and Robustness for Evolved Sorting Networks, *Proceedings of the First NASA/DoD Workshop on Evolvable Hardware*, Pasadena, CA, U.S.A, pp.255-261.

2. Stoica A., Zebulum R. and Keymeulen D. (2000), Mixtrinsic Evolution, *Proceedings of the Third International Conference on Evolvable Systems: From Biology to Hardware*, Edinburgh, U.K., pp. 208-217.

3. Thompson A. (1998), On the Automatic Design of Robust Electronics Through Artificial Evolution, *Proceedings of the Second International Conference on Evolvable Systems: From Biology to Hardware*, Lausanne, Switzerland, pp.13-24.

4. Thompson A. and Layzell P. (1999), Analysis of Unconventional Evolved Electronics, *Communications of the ACM*, **42**, 4, pp. 71-79.

5. Thompson A. and Layzell P. (2000), Evolution of Robustness in an Electronics Design, *Proceedings of the Third International Conference on Evolvable Systems: From Biology to Hardware*, Edinburgh, U.K., pp. 218-228.

6. http://www.cogs.susx.ac.uk/users/adrianth/ade.html

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