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A thesis submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy (Electrical Engineering)

Faculty of Electrical Engineering
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JUNE 2013
Dedicated to
my beloved family
ACKNOWLEDGEMENT

First and foremost, I would like to extend my deepest gratitude to my supervisor and teacher, Prof. Dr. Mohamed Khalil Hani, for giving me the opportunity to work in an amazing field of research. His constant encouragement, criticism and guidance were the key to bringing this project to a fruitful completion, especially during the final period of the research. I have learned and gained much, not only in research skills, but also in the lessons of life, which has helped shaped my character. Thanks to him, I now talk and act with better rationale and much gained wisdom. Had we not crossed paths, I would have never realized my full potential.

My sincerest appreciation goes to my co-supervisor Dr. Nadzir Marsono who was always there for me with his cheery attitude, and was of great help academically. Not to forget my seniors Jasmine Hau Yuan Wen and Rabia Bakhteri for their support, help, and technical advices. I have learned much from them, as well as receiving plenty of guidance and motivation.

I would also like to thank all those who have contributed directly and indirectly to the completion of this research and thesis. This includes my fellow postgraduate students who provided me with help and company during my study here. Otherwise, it would have been a lonely journey.

I also want to thank the original developers of the utmthesis \LaTeX project for making the thesis writing process a lot easier for me. Thanks to them, I could focus on the content of the thesis, and not waste time with formatting issues.

Finally, I would like to thank my family for always being there for me, through thick and thin. Especially my parents, who are such wonderful role models and respected members of the society. Their role in my life is something I will always need and constantly appreciate.
ABSTRACT

Evolvable neural networks are a more recent architecture, and differs from the conventional artificial neural networks (ANN) in the sense that it allows changes in the structure and design to cope with dynamic operating environments. Block-based neural networks (BbNN) provide a more unified solution to the two fundamental problems of ANNs, which include simultaneous optimization of structure, and viable implementation in reconfigurable embedded hardware such as field programmable gate arrays (FPGAs) due to its modular structure. However, BbNNs still have several outstanding issues to be resolved for an effective implementation. An efficient hardware design can only be obtained with proper design consideration. To date, there has been no previous work reported on BbNNs configured in recurrent mode for complex case studies, even though it is theoretically possible. Existing BbNN models do not explicitly specify or model the latency of the system, determine how it affects the system, nor how it can be optimized. Also, current methods of training BbNNs using genetic algorithm (GA) are slow, especially with large training datasets. This thesis presents an improved BbNN model, proposes a state-of-the-art simulation and co-design environment for it, and implements it on a hardware platform for improved speed and performance. It has a novel architecture with deterministic outputs that can evolve and operate in both feedforward and recurrent modes. The BbNN is redesigned for optimal system latency to achieve higher performance, and supports on-chip training for multi-objective optimization using a multi-population parallel genetic algorithm. All the algorithms proposed led to an efficient and scalable hardware implementation. The viability of the resulting BbNN system-on-chip (SoC) is proven with real-time performance analysis of real-world case studies, where performance improvements of up to 410× are observed. The hardware logic utilization is minimized with the help of theoretical analysis and design considerations. A case study requiring the use of recurrent mode BbNN is also presented. All case studies tested with the BbNN give equivalent or better classification accuracies compared to those provided in previous works, but with optimized latency values. As an example, the proposed BbNN solution achieves a classification accuracy of 99.41% for the heart arrhythmia case study, which is an improvement over previous work. The validity of the proposed BbNN model is thus verified.
ABSTRAK