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NEURAL NETWORKS AND SYSTOLIC ARRAY DESIGN

Editors

David Zhang

Hong Kong Polytechnic University, Hong Kong

Sankar K. Pal

The Indian Statistical Institute, Calcutta, India

World Scientific

New Jersey • London • Singapore • Hong Kong

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Preface

In recent years, Artificial Neural Networks (ANNs) have become a subject of very extensive research, since they are envisioned as an alternative to solving problems of certain tasks such as pattern recognition, vision and speech recognition, where conventional artificial intelligence techniques had been unable to tackle efficiently. Neural networks are biologically inspired; they are composed of elements that perform in a manner analogous to the most elementary functions of biological neurons. However, as simulations of large neural networks on a sequential computer frequently require days and weeks of computations, and the long computational time had been a critical obstacle to the progress in neural network research, extensive effort is being devoted to the parallel implementation of neural networks. Systolic Arrays (SAs) offer some of the best solutions to the parallel implementation of neural networks. It can overcome the communication problems generated by the highly interconnected neurons, and can exploit the massive parallelism inherent in the problem. Moreover, since the computation model of neural networks can be represented by a series of matrix by vector multiplications, the classical systolic algorithms can be used to implement them.

SA design differs from that of the conventional von Neumann computer in its highly pipelined computation. Once a data item is brought out from the memory it can be used effectively at each cell it passes while being pumped from cell to cell along the array. This is especially appealing for a wide class of compute-bound computations, where multiple operations are performed on each data item in a repetitive manner. This avoids the classic memory access bottleneck

problem commonly incurred in von Neumann machines. In addition, SA has a spatial locality and a temporal locality. It manifests a locally communicative interconnection structure, and there is at least one unit-time delay allocated so that signal transactions from one processing element to the next can be completed. When a large number of processors work together, communication becomes a significant problem. Therefore, regular and local communication in systolic arrays is advantageous.

ANNs and SAs have many similar features. The communication only between neighbor neurons in neural networks is similar to the spatial/temporal locality of systolic arrays. The highly interconnected structures of neural networks can be mapped onto the regular structure of a systolic array, and the massive parallelism can be exploited by the large number of processing elements of systolic arrays. Since SAs can overcome the communication problems generated by highly interconnected neurons, and can exploit the massive parallelism inherent in the problem, there have been several research efforts on developing systolic algorithms and systolic array structures to implement various ANNs. Attempts are made to develop a mapping approach, in which the systolic algorithms are partitioned and mapped onto the parallel computers, and a VLSI approach, in which VLSI systolic arrays dedicated to specific models are designed.

This book provides a collection of sixteen chapters containing tutorial articles and new material describing, in a unified way, the basic concepts, theories and characteristic features of integrating and formulating different facets of ANNs and SAs, with recent developments and significant applications. The articles, written by various experts from around the world, demonstrate the varied ways this integration can be made to design methodologies, algorithms and architectures, and implementations for ANN applications efficiently. With the exception of the first chapter's tutorial introduction to ANNs and SAs, each chapter provides exhaustive information on developments in the respective areas, keeping a cohesive character with other chapters. The approaches typically include the mapping of systolic algorithms for neural networks onto parallel computers and the design of VLSI systolic arrays dedicated to one or two specific models, besides describing some available systems and applications.

They also provide a balanced mixture of both theory and implementation.

This book, which is unique in character, is useful to graduate students and researchers in computer science, electrical engineering, systems science and information technology not only as a reference, but also as a text book for some parts of the curriculum. The researchers and practitioners in industry and R&D laboratories working in the fields of system design, VLSI, parallel processing, control, pattern recognition, neural networks and vision will also benefit.

We would like to take this opportunity to thank all the contributors for agreeing to write for the book. We owe a vote of thanks to Ian Seldrup and Alan Pui of World Scientific, Singapore, for taking the initiative in bringing the volume out. The technical/software support provided by Adams Kong, Michael Wong, Henry Ko and Yunzhi Lin are also acknowledged. The project was initiated when Prof. S.K. Pal was working as a Visiting Professor in the department of computing, Hong Kong Polytechnic University, Hong Kong, during November-December 2000.

David Zhang and Sankar K. Pal
December 2001

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