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Computational Electromagnetics and Supercomputer Architecture

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T. Cwik and J. Patterson

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PREFACE

Volume Seven of the Progress in Electromagnetic Research series considers the use of advanced supercomputer architecture in computational electromagnetics. The evolution of computer hardware and software has enabled numerical simulation to be a vital component in electromagnetic engineering design for electrically larger scale sizes and for more complex structures. Traditional computational methods are being used to simulate components and systems in greater detail and accuracy due to significantly larger memory and quicker turn-around time in a design iteration. For similar reasons, newer techniques, e.g., finite methods, are being developed to model the even finer volumetric structure that exists in many electromagnetic systems, and to effectively utilize the rapid increase of memory capacity and computer throughput as it becomes available. This book is intended for students and engineers in the various branches of electromagnetics who make use of computational methods for design and whose work is propelled by the continuous advancement of computer systems.

The definition of a "supercomputer" is constantly being modified. Over the last 10 years major advances have been achieved in processor and bandwidth performance, and in the availability of relatively inexpensive large memory. For instance, individual processors in the mid-1980s typically ran at about a hundred thousand floating point operations per second. Now, a decade later, new Reduced Instruction Set Computer (RISC) processors are available with better than 1000 times that performance. Likewise, the bandwidth and memory technologies have made significant strides.

The challenge to integrate these components into high performance, yet easily programmable processing systems has introduced a number of novel and interesting architectures. Some machines have been developed which utilize massive numbers of fine grain (i.e., small memory) processors aggregated into a single system. These systems tend to be "Single-Instruction Multiple-Memory" (SIMD) architecture, where each processor runs the identical instruction set in lock step but has its own set of data. The Thinking Machine Corporation's first and second generation machines, Connection

Machine (CM-1 and CM-2), are examples. Other computer architects have elected to configure systems with fewer processors but have placed larger memory into each processor. These systems tend to be "Multiple-Instruction Multiple-Data" (MIMD) systems, where each processor executes its own code independently of other processors. Examples of MIMD-style architecture are the Intel and NCUBE Hypercubes. Both the SIMD and MIMD systems can communicate data via programmer-specified message passing. For some systems, a notion of global data is preserved, allowing the programmer to ignore the details of processor communications. The more traditional supercomputers, such as those produced to date by Cray Research, have utilized a modest number of large memory processors with vector operations capabilities to achieve very high performance.

This volume is a collection of papers describing computational electromagnetic applications which utilize supercomputing systems. An introduction to the theme of this volume is presented in the Chapter 1, "Computational Electromagnetics and Supercomputer Architecture." A number of different applications and numerical techniques that are now commonly used for solution of electromagnetic problems have been implemented on a diverse set of supercomputers. Chapter 2 describes problems running on vector supercomputers where numerical techniques are developed to exploit the high performance offered by pipelined vector processors. In Chapters 6 and 8 method of moment and finite difference solutions are described using SIMD architecture. These approaches take advantage of the high degree of homogeneity in the algorithms to obtain excellent performance on these systems. Chapters 3 and 4 detail partial differential equation methods developed on MIMD systems where the irregular nature of the problem domain is well-suited to asynchronous processing. In Chapter 5 the integral equation moment method is implemented on MIMD architecture and can be compared with the SIMD implementation described in Chapter 6. The growth of high performance numerical algorithms which can be accessed as library mathematical subroutines is critical for rapid development of efficient parallel codes. Chapter 7 describes the approach and performance of an out-of-core dense matrix factorization and solution subroutine library designed for optimal performance on

Intel MIMD systems. Finally, a listing of machines and their performance on benchmark problems is given in the Appendix.

It can be argued that some of the material in this volume is outdated due to the rapid advancement of computer systems – especially the recent progress in parallel architecture. Indeed, this is true of any research subject – some material may be already outdated when the author finishes typing. The reader will note that even though wall clock time or machine performance measurements for some computations are not current, the underlying algorithms, or variations of them, are presently used on state-of-the-art machines. In most examples, the numerical techniques presented are directly extendible to faster and larger machines. In several of the chapters, addendums were added at the time of publication showing current results.

Individual acknowledgments can be found at the end of each chapter in the book. The editors wish to thank the authors for their contributions, the reviewers for reviewing the chapter manuscripts, and Stephanie Nelson for her superb editing and for indexing this volume.

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