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VALU, AVX and GPU Acceleration Techniques for Parallel FDTD Methods

Wenhua Yu, Xiaoling Yang and Wenxing Li

THE ACES SERIES ON COMPUTATIONAL ELECTROMAGNETICS AND ENGINEERING

VALU, AVX and GPU Acceleration Techniques for Parallel FDTD Methods

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ACES Series

Wenhua Yu
2COMU and Harbin Engineering University
Xiaoling Yang
2COMU
Wenxing Li
Harbin Engineering University

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Series Editor Foreword

The ACES series on Computational Electromagnetics and Engineering strives to offer titles on the development and application of numerical techniques, the use of computation for engineering design and optimization, and the application of commercial modeling tools to practical problems. The discipline of computational electromagnetics has always pushed the limits of the available computer power, and will continue to do so. Recent developments in multiprocessor computer hardware offer substantial gains in performance, if those features can be fully utilized by software developers. Unfortunately, compilers that automatically exploit hardware advances usually lag the development of the hardware.

The present book is a valuable addition that should help readers meet the challenges provided by modern hardware, and improve the performance of their codes. This text provides a significant level of detail about issues such as the optimization of cache memory, control of the vector arithmetic logic unit, and use of the graphical processing unit to improve computational performance. These techniques are described in the context of the popular finite-difference time domain (FDTD) method of electromagnetic analysis. The authors have also included source code to facilitate the implementation of their ideas. While the authors use the FDTD approach for illustration, readers who are primarily interested in other methods should also benefit. The book also offers an introduction to cloud computing, with a discussion of a wide range of issues related to that type of service.

Andrew F. Peterson
July 18, 2013

Preface

Multi-core CPU computers, multi-CPU workstations, and GPU are popular platforms for scientific research and engineering applications today. Achieving the best performance on existing hardware platforms is, however, a major challenge. In addition, distributed computing has become a primary trend due to its high performance at low cost for hardware and network devices. This book introduces the vector arithmetic logic unit (VALU), advanced vector extensions (AVX) and graphics processor unit (GPU) acceleration techniques to (1) speed up the electromagnetic simulations significantly and (2) use these acceleration techniques to solve practical problems in the parallel finite difference time domain (FDTD) method. Both VALU and AVX acceleration techniques do not require any extra hardware devices.

Three major computational electromagnetic methods – FDTD method, method of moments (MoM), and the finite element method (FEM) – are popularly used in solving various electromagnetic problems concerned with antennas and arrays, microwave devices and communication components, new electromagnetic materials, and electromagnetic radiation and scattering problems. Among these methods, the FDTD method has become most popular due to its simplicity, flexibility, and ability to handle the complex environment of electromagnetic problems. In this book, we apply VALU and AVX capabilities inside the standard CPUs and GPU to accelerate the parallel FDTD method. VALU is operated by the streaming SIMD extensions (SSE) instruction set originally designed by Intel and AMD for the multimedia area. AVX, released in 2011, is the extension of VALU, and its vector length is extended from 128 bits to 256 bits. GPU is a popular topic today in computational techniques, so we discuss its application in the parallel FDTD method in this book. Compute unified device architecture (CUDA) allows the programming of GPUs for parallel computation without any graphics knowledge. We introduce how to implement CUDA in the parallel FDTD method.

Cloud computing is one of the popular computing services that does not require end-user knowledge of both physical location and configuration of the computing resource. Cloud computing includes two key aspects, namely, virtual resources and web browser tools. This book introduces the basic idea of cloud computing related to the electromagnetic simulation techniques.

A high-performance code is a key to achieve the best simulation performance on a given hardware platform. This book demonstrates a parallel 3-D FDTD code enhanced by the VALU acceleration techniques. The superior performance has been validated in Chapter 6 for various engineering problems on both Intel and AMD processors.

This book includes seven chapters and one appendix. The first chapter briefly introduces the parallel FDTD method. Chapter 2 presents the VALU and AVX acceleration techniques using the SSE and AVX instruction sets in the parallel FDTD method followed by three simple examples to demonstrate the acceleration performance. Chapter 3 shows how to implement the SSE instructions to accelerate the CPML boundary condition. Chapter 4 introduces the three-level parallel processing techniques, including OpenMP, MPI, and their combination with the SSE instruction set. Chapter 5 presents the basic concept, implementation, and engineering applications of GPU acceleration techniques. Chapter 6 presents some engineering problems in various applications such as antenna arrays, radiation and scattering problems, microwave components, and finite and curved frequency selective surface (FSS) structures. Finally, Chapter 7 introduces the cloud computing technique and its applications in the electromagnetic field area. The appendix includes a 3-D parallel FDTD code with the CPML boundary condition enhanced by the VALU acceleration technique.

This book is appropriate for advanced senior and graduate students in electrical engineering and for professors in areas related to electromagnetic computing techniques, computer science, and hardware acceleration techniques. This book is also good for any students, engineers, or scientists who seek to accelerate numerical simulation and data processing techniques.

The authors would like to thank Prof. Atef Elsherbeni and Prof. Veysel Demir for their contributions to Chapter 5.

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