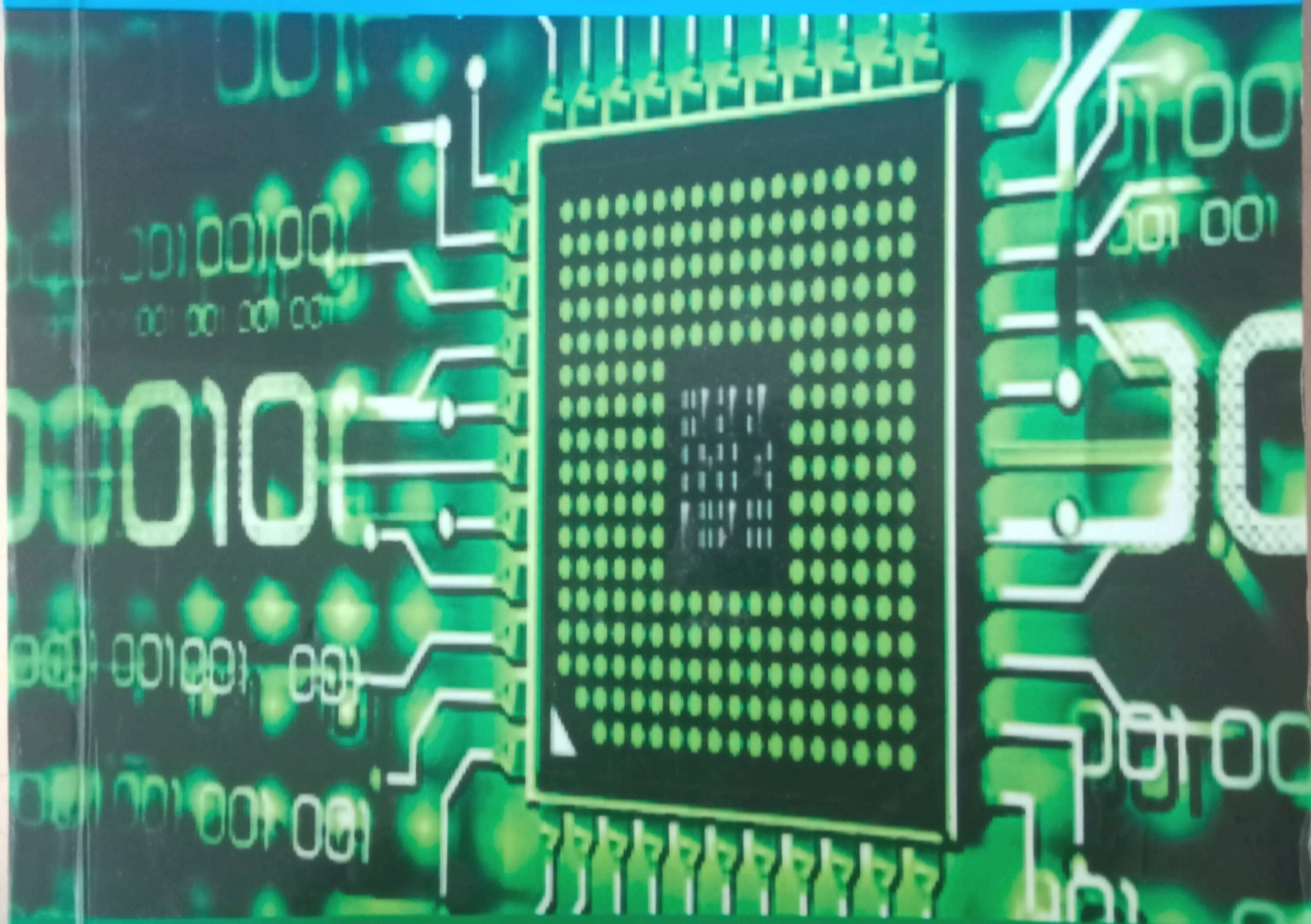


MULTICORE ARCHITECTURES AND PROGRAMMING



SOBINI X. PUSHPA
A.BAMILA VIRGIN LOUIS
Dr. G. ARUL DALTON

MULTICORE ARCHITECTURES AND PROGRAMMING

SOBINI X. PUSHPA

Assistant Professor

Department of Computer Science and Engineering
St. Xavier's Catholic College of Engineering, Nagercoil.

A.BAMILA VIRGIN LOUIS

Assistant Professor

Department of Computer Science and Engineering
St. Xavier's Catholic College of Engineering, Nagercoil.

Dr. G. ARUL DALTON

Professor

Department of Computer Science and Engineering
Princeton Institute of Engineering and Technology for Women, Hyderabad.

Multicore Architectures and Programming

By

Sobini X. Pushpa

A. Bamila Virgin Louis

Dr. G. Arul Dalton

Copyright © 2019 Exclusive by Sobini X. Pushpa, Author

All rights reserved.

No part of this publication should be reproduced in any form without the prior permission of the author.

Price: Rs.250/-

ISBN: 978-93-5361-325-9

Publisher: Self-Publishing

Printer:

Win Tech Computers,
Rajakamangalam Road,
Chettikulam Jn,
Nagercoil,
Tamil Nadu - 629 002.

Dedicated to
our
Beloved Parents

Preface

It gives us immense pleasure to publish the book titled "MULTICORE ARCHITECTURES AND PROGRAMMING". This book offers the fundamental and programming concepts of Multicore architectures and describes the differences between single-core and multi-core systems. It also addresses the parallel programming concepts and its challenges. This book has been framed as per the Anna University syllabus and can be used as text book for the students.

Organization of book:

Chapter 1: This chapter gives introduction to single-core and multi-core architectures. It describes the interaction between hardware and software in multicore machines. It also provides basic idea about parallel program design and explores the performance of parallel programs.

Chapter 2: This chapter deals with parallel programming challenges like synchronization and data sharing. It helps the students to understand various synchronization methods and coordination mechanism available on latest multicore machines.

Chapter 3: This chapter introduces OpenMP programming for shared memory systems. The directives and library functions used in OpenMP are explained in an understandable way. It enables the students to identify the challenges in writing efficient programs for shared memory architecture.

Chapter 4: This chapter introduces MPI programming for distributed memory systems. It helps the students to learn about various parallel programming paradigms like MPI constructs and library functions for distributed memory architecture.

Chapter 5: This chapter deals with the case study of n-body solver problem and tree search problem. Detailed implementations of these case studies using OpenMP programming and MPI programming also included. Comparison between OpenMP and MPI programming helps the students to understand the concept easily.

At the end of this book, possible two marks questions with answers and previous year Anna University question papers also included for the betterment of students.

Syllabus

MULTI-CORE ARCHITECTURES AND PROGRAMMING (CS6801)

UNIT I MULTI-CORE PROCESSORS

Single core to Multi-core architectures – SIMD and MIMD systems – Interconnection networks - Symmetric and Distributed Shared Memory Architectures – Cache coherence - Performance Issues – Parallel program design.

UNIT II PARALLEL PROGRAM CHALLENGES

Performance – Scalability – Synchronization and data sharing – Data races – Synchronization primitives (mutexes, locks, semaphores, barriers) – deadlocks and livelocks – communication between threads (condition variables, signals, message queues and pipes).

UNIT III SHARED MEMORY PROGRAMMING WITH OpenMP

OpenMP Execution Model – Memory Model – OpenMP Directives – Work-sharing Constructs - Library functions – Handling Data and Functional Parallelism – Handling Loops - Performance Considerations.

UNIT IV DISTRIBUTED MEMORY PROGRAMMING WITH MPI

MPI program execution – MPI constructs – libraries – MPI send and receive – Point-to-point and Collective communication – MPI derived datatypes – Performance evaluation.

UNIT V PARALLEL PROGRAM DEVELOPMENT

Case studies - n-Body solvers – Tree Search – OpenMP and MPI implementations and comparison.

Table of Contents

Chapter - I	MULTI-CORE PROCESSORS	
1.1 SINGLE CORE TO MULTI-CORE ARCHITECTURES		1
1.1.1 The von Neumann architecture		2
1.1.2 Processes, multitasking, and threads		3
1.1.3 Modifications to the Von Neumann Model - Multicore processor		3
1.1.4 Types of Hardware multithreading		5
1.1.5 Characteristics of Multicore processor		5
1.2 SIMD AND MIMD SYSTEMS		8
1.2.1 SIMD systems		8
1.2.2 MIMD systems		11
1.3 INTERCONNECTION NETWORKS		13
1.3.1 Shared-memory interconnects		13
1.3.2 Distributed-memory interconnects		14
1.4 SYMMETRIC AND DISTRIBUTED SHARED MEMORY ARCHITECTURES		17
1.5 CACHE COHERENCE		19
1.5.1 False sharing		21
1.6 PERFORMANCE ISSUES		23
1.6.1 Speedup and Efficiency		23
1.6.2 Scalability		26
1.7 PARALLEL PROGRAM DESIGN		27
1.7.1 Steps to convert serial program into a parallel program		27
1.7.2 Example: A serial Program		27
1.7.3 Parallelizing the serial program		29

Chapter - II	PARALLEL PROGRAM CHALLENGES	32
2.1	PERFORMANCE – SCALABILITY	33
2.2	SYNCHRONIZATION AND DATA SHARING	36
2.2.1	DATA RACES	36
2.2.2	Tools to Detect Data Races	38
2.2.3	Avoiding Data Races	41
2.3	SYNCHRONIZATION PRIMITIVES	41
2.3.1	Mutexes and Critical Regions	42
2.3.2	Spin Locks	43
2.3.3	Semaphores	44
2.3.4	Recursive Locks	47
2.3.5	Readers-Writer Locks	47
2.3.6	Barriers	48
2.4	DEADLOCKS AND LIVELOCKS	50
2.4.1	Deadlock	50
2.4.2	Livelock	52
2.5	COMMUNICATION BETWEEN THREADS AND PROCESSES	52
2.5.1	Condition Variables	52
2.5.2	Signals and Events	55
2.5.3	Message Queues	56
2.5.4	Named Pipes	56
Chapter – III	SHARED MEMORY PROGRAMMING WITH OpenMP	58
3.1	OpenMP EXECUTION MODEL	59
3.1.1	Compiling and running OpenMP programs	59
3.2	OPENMP MEMORY MODEL	63

3.2.1 OpenMP flush operation	64
3.3 OpenMP DIRECTIVES	66
3.3.1 Parallel Region Construct	67
3.3.2 Synchronization Constructs	69
3.3.3 Work-Sharing Constructs	76
3.4 DATA SCOPE ATTRIBUTE CLAUSES	82
3.5 OpenMP LIBRARY FUNCTIONS	87
3.5.1 Environment Variables	90
3.6 HANDLING DATA AND FUNCTIONAL PARALLELISM	92
3.7 HANDLING LOOPS	92
3.8 PERFORMANCE CONSIDERATIONS - OpenMP	95
Chapter – IV DISTRIBUTED MEMORY PROGRAMMING WITH MPI	99
4.1 MPI PROGRAM EXECUTION	100
4.1.1 Compilation	101
4.2 MPI CONSTRUCTS	104
4.3 LIBRARIES	104
4.3.1 Point to point communication routines	104
4.3.2 Collective communication routines	107
4.3.3 Derived data type routines	109
4.4 MPI SEND AND RECEIVE	110
4.4.1 Semantics of MPI_Send and MPI_Recv	114
4.5 POINT-TO-POINT COMMUNICATION	115
4.5.1 .Blocking communication	115
4.5.1 .Non- blocking communication	117
4.6 COLLECTIVE COMMUNICATION	118
4.6.1 Tree structured communication	118

4.6.2 Collective communication routines	119
4.6.3 Collective Vs Point to point communication	122
4.7 MPI DERIVED DATA TYPES	131
4.8 PERFORMANCE EVALUATION OF MPI PROGRAMS	134
Chapter – V PARALLEL PROGRAM DEVELOPMENT	139
5.1 TWO <i>n</i> -BODY SOLVERS	140
5.1.1 Parallelizing the <i>n</i> -body solvers	145
5.1.2 Parallelizing the basic solver using OpenMP	147
5.1.3 Parallelizing the reduced solver using OpenMP	150
5.1.4 Parallelizing the basic solver using MPI	154
5.1.5 Parallelizing the reduced solver using MPI	156
5.2 TREE SEARCH	160
5.2.1 Recursive depth-first search	162
5.2.2 Non-recursive depth-first search	163
5.2.3 Parallelizing tree search	165
5.2.4 Parallelizing the tree-search programs using OpenMP	167
5.2.5 Implementation of tree search using MPI and static partitioning	170
5.2.6 Implementation of tree search using MPI and dynamic partitioning	174
5.3 COMPARISON BETWEEN OpenMP AND MPI PROGRAMMING	177
TWO MARKS QUESTIONS AND ANSWERS	179
IMPORTANT QUESTIONS	199
UNIVERSITY QUESTION PAPERS	202

MULTICORE ARCHITECTURES AND PROGRAMMING

This book offers the fundamental and programming concepts of Multicore architectures and describes the differences between single-core and multi-core systems. It addresses various parallel programming techniques like OpenMP and MPI to increase program performance in multi-core architectures. The book is organized based on Anna University syllabus and it provides detailed explanation to understand the concepts. The main objective is to facilitate the parallel programming skills for shared and distributed memory architectures. Two marks question answers and Anna University question papers are also included, which will help students for better preparation.

ISBN: 978-93-5361-325-9



9 789353 613259