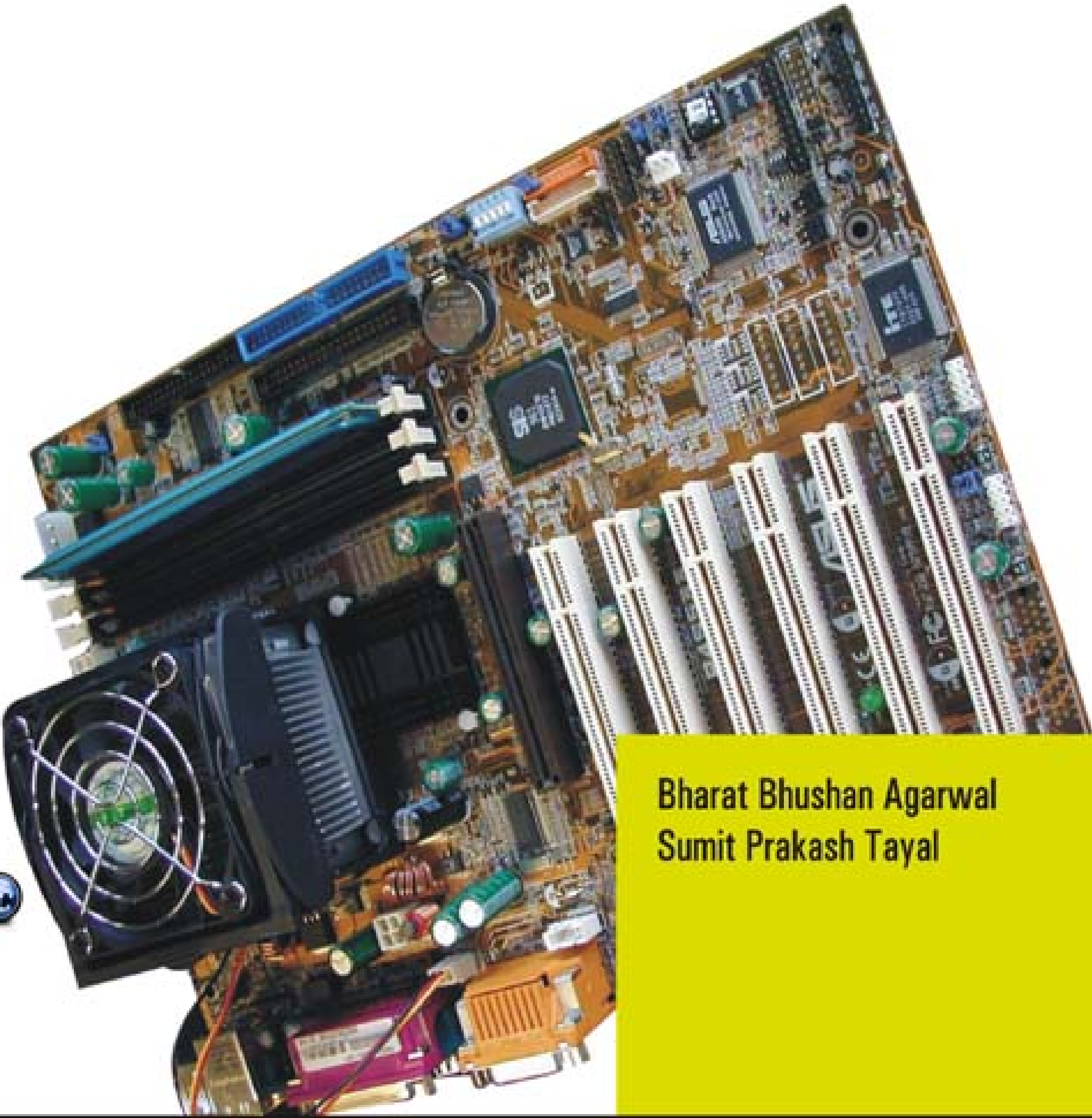
COMPUTER ARCHITECTURE AND PARALLEL PROCESSING



Bharat Bhushan Agarwal
Sumit Prakash Tayal

COMPUTER ARCHITECTURE AND PARALLEL PROCESSING

(For B.Tech., M.Tech., BCA, MCA, B.Sc. (Comp. Science) and IT Professionals)

By

Bharat Bhushan Agarwal
B.E. (CS & IT) (Honours), M.Tech.
Sr. Lecturer, Deptt. of Computer Engineering
College of Engineering Technology (I.F.T.M.)
Moradabad, Uttar Pradesh

Sumit Prakash Tayal
B.Tech. (Electronics)
Solutions Developer
Engineering and Design Group
Tata Technologies Ltd.,
Pune, Maharashtra

UNIVERSITY SCIENCE PRESS
(An Imprint of Laxmi Publications Pvt. Ltd.)

BANGALORE ● CHENNAI ● COCHIN ● GUWAHATI ● HYDERABAD
JALANDHAR ● KOLKATA ● LUCKNOW ● MUMBAI ● RANCHI
NEW DELHI

Published by :

UNIVERSITY SCIENCE PRESS

(*An Imprint of Laxmi Publications Pvt. Ltd.*)
113, Golden House, Daryaganj,
New Delhi-110002

Phone : 011-43 53 25 00
Fax : 011-43 53 25 28

www.laxmipublications.com
info@laxmipublications.com

Price : **Rs. 110.00** *Only.* *First Edition* : 2009

OFFICES

✆ **Bangalore**	080-26 61 15 61	✆ **Chennai**	044-24 34 47 26
✆ **Cochin**	0484-237 70 04, 405 13 03	✆ **Guwahati**	0361-254 36 69, 251 38 81
✆ **Hyderabad**	040-24 65 23 33	✆ **Jalandhar**	0181-222 12 72
✆ **Kolkata**	033-22 27 43 84	✆ **Lucknow**	0522-220 95 78
✆ **Mumbai**	022-24 91 54 15, 24 92 78 69	✆ **Ranchi**	0651-221 47 64

UCA-9249-110-COMP ARCH & PARALLEL PROCES **C—15886/08/05**

Typeset at : Kalyani Computer Services, New Delhi. *Printed at* : Mehra Offset Press, Delhi.

Dedicated
to
Our Parents

CONTENTS

PREFACE

Computer Architecture and Parallel Processing is more of an art than science. It covers computer system, microprocessors, circuits & system programs. High speed computing deals with designing very high performance computing systems architecture. Due to technological limits on the basic raw speeds of the circuits, computer architects employ various techniques to obtain the high performance. This volume deals with the architectural principles and theory in synchronous parallel systems employing temporal as well as spatial parallelism. It presents complete theoretical treatment of the topics of relevance in these architectures.

This book is designed to cover the syllabus for undergraduate as well as postgraduate students of different Indian universities, who study computer organization as a part of their curriculum. This book gives the basic knowledge necessary to understand the operation of digital computer.

Several features of this book are:

It is designed to make it particularly easy for students of B. Tech., M. Tech., MCA, BCA, to understand Computer Architecture.

It highlights the basic principles and contrasts their application in specific areas of technology.

It contains a number of examples, various diagrams & exercises, which enhance its suitability for classroom instructions.

Though great care has been exercised by us to make the contents of this book very useful and help students to be in touch with modern developments.

We hope that the book will fulfill the need of readers and would welcome any suggestions, and constructive criticisms regarding the improvement of this book.

—Authors

ACKNOWLEDGEMENT

First and foremost, we must extend our deepest gratitude to the Almighty God for showering love and grace on us to make us write this book.

We feel privileged and fortunate enough to retain the affection of the following distinguished personalities, Shri Rajeev Saran Kothiwal, Chairman, IFTM Moradabad, Dr. R. M. Dubey, the Managing Director IFTM Moradabad & Mr. Prakash M. Telang, Executive Director (Commercial Vehicles), Tata Motors Limited, Pune who have been the driving force behind this effort.

We are extremely indebted to Prof. Anupam Srivastava, Director, C.E.T, IFTM, Moradabad for inspiring and motivating us, without whose valuable suggestions it would have been difficult to complete the book.

We express our special gratitude, very heartly, to Prof. B.N. Kaul Dean Administration CET, IFTM Moradabad, time-to-time suggestions & guidance.

Special thanks are also to Mr. G.S. Singh, Practice Head, Tata Technologies Ltd. Pune, Mr. Ramraj Pandey, Consultant, Chrysler, U.S.A., Mr. Rahul Shandilya, Project Manager, Mr. P.W. Dandekar, Tata Technologies Ltd. Pune, and Mr. R. Pandian, Project Manager who have guided, encouraged and advised us during the process of writing the book.

We would also like to thank to Prof. S.K. Srivastava, Advisor, CET., I.F.T.M, Moradabad & Mr. M.I.H Ansari (Head, Dept. of Computer Applications, I.F.T.M. Moradabad) for their moral support & encouragement for the completion of this book.

We wish to put on record our sincere thanks, honor, and gratitude to our close family members Shri K.B. Agarwal, Shri Akhilesh Kothiwal and Shri Sandeep Agarwal (brother), consecutive four times elected as MLA of Moradabad (U.P.) for their soft words, continuous encouragement & necessary help whenever required.

We would also like to offer their warm thanks to Prof. (Dr.) A.K. Nayak, Director, School of Computer Sciences Indian Institute of Business Management Patna, Dr. A.K. Raghav, Director of Alfalah School of Engg. & Tech. Dauj (Faridabad) for their valuable contributions.

Sincere thanks are also due to Prof. Dinesh Chandra & Shri Suneet Shukla, HOD. Department of Computer Science, CET, IFTM Moradabad & Dr. Vivek Kumar, HOD. Department of Info. Tech., Galgotia, Gr. Noida, Dr. Parmanand Astya, HOD. Department of Computer Science, Galgotia, Gr. Noida, Mr. S. S. Bedi, Head of Deptt. CS & IT Engg. & Tech., Rohilkhand, Bareilly, Dr. O.P. Singhal, Head—CS Dept. IDEAL, Ghaziabad, Mr. L.S. Maurya, HOD. Department of Information Technology, SRMS, Bareilly & Dr. R.K. Gupta (Tauji) Principle of MBBS, TMIMT, Moradabad, Mr. Vikas Mittal, Head of Deptt. CS & IT, M.I.T., Moradabad, Mr. Yogesh Sharma, Head of CS-Deptt., S.D. College of Engg. & Tech., for their encouragement & critical suggestions.

Along with our colleagues—(Dr. B.K. Singh (Chief Proctor), Dr. Nikhil Rastogi, Mr. lntezar Mahdi, Dr. Vikas Gupta, Mr. Rahul Mishra—CET, IFTM MBD) who have helped & motivated us for writing this book.

We would like to acknowledge our special thanks to our well-wishers (Dr. Manish Saxena, Dr. Animesh Agarwal, and Shri Kshitij Shinghal, MIT, MBD) for valuable suggestions. We would like to thank Mr. Akhtar Hussain, (MJP, Rohilkhand, Bareilly) & Manoj Kr. Chubey (GLA, MATHURA) for their cooperation in this project.

Also, we would like to express our heartiest thanks to Ms. Shivangi Dhall & Mr. Dhiraj Dhall for their deep involvement in this project.

So, special acknowledgement to the postgraduate colleagues Raj Kumar Goel, Vikram Bali, Prateek Srivastava, Anita Sahoo, Kanchan Singh, Pavitra Rani Gautam, Sarika Khandelwal, Rashmi Singh, Hitendra Agarwal, Vikas Lamba, Anupama Sharma, Dharmendra Kumar Tripathi, Kulwant Singh Patel, Lavkush Sharma, Mahendra Prasad Sharma, Varsha, Pritee Gupta, Narendra Kumar, Niraj Kumar Singh, Nitin Goyal, Prachi Vats, Promod Kumar Yadav, Narvada Chaudhary, Rinki, Sachin Ahuja, Sanjay Kumar Nayak, Uma Shankar Sharma, Ankit Vishnoi, Mohit Agarwal.

We are indebted to all the seniors, colleagues and juniors of Tata Technologies Ltd. and CS & IT Dept. of CET, IFTM Moradabad during the whole process of writing the book.

We through our indebtedness to our parents, Shri Ravi Prakash Agarwal and Smt. Bindu Agarwal for their perpetual love and concern, which cannot be summed up in words.

Sincere thanks are also due to our sister Smt. Anupam Agarwal & brother-in-law Shri Shakshi Goel for their words of cheer & encouragement & special thanks to little Shubhangi & Gauri for bearing with us at odd hours.

Finally, we thank every one, who contributed significantly in accomplishing this job.

—Authors

Chapter 1

FUNDAMENTALS OF COMPUTER ARCHITECTURE

1.1 COMPUTATIONAL MODEL

Computational models are created to simulate a set of processes observed in the natural world in order to gain an understanding of these processes and to predict the outcome of natural processes given a specific set of input parameters.

1.1.1 Introduction

The creation of computational modeling software has grown at an accelerating rate since the earliest applications to the modeling of real-world phenomena during the 1940s. Supported by increasingly powerful hardware, software and networking environments, growing numbers and varieties of computational models are being developed to support research, development and education in all areas. For a variety of historical and technical reasons, including major problems of interoperability at all semantic levels and weak support for "publishing" computational models, library-based mechanisms to support the widespread distribution and use of modeling software have been slow to develop. While distributed digital libraries (DLs) and the worldwide web offer a natural infrastructure for such distribution, critical aspects of an effective infrastructure have yet to evolve. In particular, there are no generally accepted procedures for describing computational models in ways that support cataloging, search, selection and use.

1.1.2 Content Standard for Computational Models (CSCM)

This Content Standard for Computational Models (CSCM) was developed partly in response to the general need for such descriptions and partly in response to the immediate needs of the Alexandria Digital Earth Project (ADEPT) at the University of California, Santa Barbara (UCSB). ADEPT is developing services that facilitate the construction of personalized digital collections that support learning in a variety of contexts. Since the Project views computational models of environmental phenomena as critical DL resources for helping students understand and reason scientifically about natural and human-influenced phenomena, it is useful to provide a metadata framework to standardize the way in which modeling software is described so that models can be integrated into DLs with other types of information in support of education and learning.

1.1.2.1 Content Standards and Computational Modeling Software

The primary purpose of CSCM is to provide enough information that potential users of the model (other than its creators) have a reasonable chance of finding it in a distributed DL environment, evaluating its potential applicability for their purposes (*e.g.*, research, education), obtaining it, running it successfully in some computational environment and with appropriate datasets and understanding the results. Computational modeling software will process certain kinds of data and produce specified output; it will incorporate certain variables and parameters; it will have known limitations and will be more suitable for some uses than for others; it may operate only in some computational environments and may require that other software packages be simultaneously available; and its use may be subject to licensing agreements. It is important to provide potential users with an understanding of these aspects and also with a sense of the theoretical and computational choices made by the modeler to represent the real-world phenomenon. All of these characteristics need to be documented in metadata, along with contact information for obtaining the software or getting help in using it.

In relation to these primary goals, we note that the standard is not intended to define the manner in which the information is presented to a user, but to specify a description framework to support search, retrieval and evaluation. The design of user interfaces and report presentations is an independent activity based on the metadata structure. We also note that the standard is not currently specified to the point of being able to fully support machine-machine analogs of such activities.

In developing a CSCM, one must resolve some issues that are generic to metadata standards and others that are specific to computational models. There exist many definitions of models in general and computational models in particular (Aris, 1978 (reprinted 1994); Benz, 1997; Chorley, 1967; Dee, 1994). An adequate core definition of *computational models* for current purposes is:

"A set of computational codes, executable in some software/hardware environment, that transform a set of input data into a set of output data, with the input, output and transformation typically having some interpretation in terms of real-world phenomena."

1.1.2.2 Examples of Models

Two specific examples of models satisfying this broad definition have been described using this initial version of the CSCM to test the design of the content standard.

The first model (Smith, 2001) takes the form of a set of C-Language codes that transform two initial input datasets into two output datasets. The input datasets represent a land surface and a flow of water over the surface; the transformation represents a time-dependent erosion process; and the two output datasets represent the land surface and water flow field at later times.

The second example (Clarke, 2001) is a cellular automation model of urban growth where multiple datasets showing a variety of land cover properties for at least four urban time periods are used for input and the output visualizes and predicts urban growth into the future by using urban growth coefficients. Model metadata will continue to be created for the ADEPT project, with modifications to the CSCM as necessary.

1.1.2.3 General Considerations

Several general considerations arise in deciding how to structure a content standard for computational modeling software.

First, the syntactic and semantic complexity of many models makes it difficult to provide a definitive metadata description of reasonable length, more difficult than in the case of many other classes of digital objects. Hence, a specific strategy has been to assume that search, evaluation and use are typically iterative processes, requiring that the metadata contain pointers to more detailed information, which in turn may contain other pointers.

Second, it is useful to have a conceptual framework to help guide the design of a content standard for computational models. We view models as generally having four increasingly specific levels of representation, in both syntactic and semantic terms. These are the conceptual, symbolic, algorithmic and coding representations of the model.

1.1.2.4 Representation Describes the Model

The *conceptual* representation describes the model at the highest level. For the erosion model, for example, it would characterize the model in terms of land and water surfaces and the conservation of water flowing over a surface and the conservation of sediment eroded from the surface and transported by the water.

The *symbolic* representation is typically, but not always, in terms of some mathematical or logical language with an interpretation of the symbols in terms of real-world phenomena.

In the case of the erosion model, this representation takes the form of two partial differential equations. The *algorithmic representation* provides a high-level view of how the symbolic representation is converted into a set of computations, while the *coding representation* of these algorithms provides codes that are, or can be compiled into, executables in some specific computing environment. The erosion model, for example, is specified at the algorithmic level by indicating that the water flow equation is transformed into a finite difference scheme using an upwind scheme and that the land surface erosion equation is transformed into a finite difference scheme using a Crank-Nicholson scheme. At the coding level, it is specified by a set of C-language programs and the environment in which they would run. Hence we may view the information represented in these four categories as moving from a high-level description of the model and its applicability to the details needed to execute it in a specific computation environment. The ADEPT CSCM provides a structure for these levels of description through narrative elements and elements for specific details of input and output variables, parameters, datasets and processing flow.

The CSCM consists of approximately 165 elements divided into the following ten sections:

1. Identification Information
2. Intended Use
3. Description

4. Access or Availability
5. System Requirements
6. Input Data Requirements
7. Data Processing
8. Model Output
9. Calibration Efforts and Validation
10. Metadata Source

1.1.2.5 Content Standard Issues of CSCM

Of the many issues related to the design of the CSCM, the following are highlighted because they were central to our internal discussions.

1. *Scope of models to be covered by the CSCM:* This content standard is designed to describe computational models that have adjustable variables and parameters. This includes two basic sets of computational models: (1) modeling software and (2) modeling software that is packaged with datasets. Packages that contain both software and datasets are often published to illustrate specific phenomenon and to teach specific theoretical principles. Animations and simulations and similar visualizations that do not include adjustable variables and parameters are not covered by the CSCM.
2. *Metadata design:* Our goal is to create a metadata structure comprehensive enough to describe a wide variety of computational models and similar enough to existing metadata structures for other types of objects (*e.g.*, datasets, texts, photographs) to facilitate the incorporation of modeling software into DLs. Our design for element and entity definition is based on the metadata designs of the geospatial community (International Organization for Standardization (ISO), 2000; U.S. Federal Geographic Data Committee, 1998). The following section describes this approach in detail. As far as possible, we have tried to reuse sets of common elements for describing identification and descriptive aspects of models.
3. *Order of metadata sections and elements:* The beginning sections include elements for narrative statements that give overviews of the model to help a potential user develop an overall understanding of what the model does and how it does it. Details of variables, parameters, input datasets, operating environments, processing functions and outputs are left for later sections. A report/presentation might choose to list the details and the narrative statements in a different order.
4. *Links to external files:* At several points in the CSCM, elements are provided to link to files of documentation about the model and to related information. In some cases, the metadata is written so that if the information covered by a set of elements is contained in an external file (e.g., descriptions of the variables, parameters and processing flow) then the elements become “optional”; that is, the information does not have to be repeated in the metadata itself.

Computer Architecture & Parallel Processing By B.B.Agarwal & S.P.Tayal