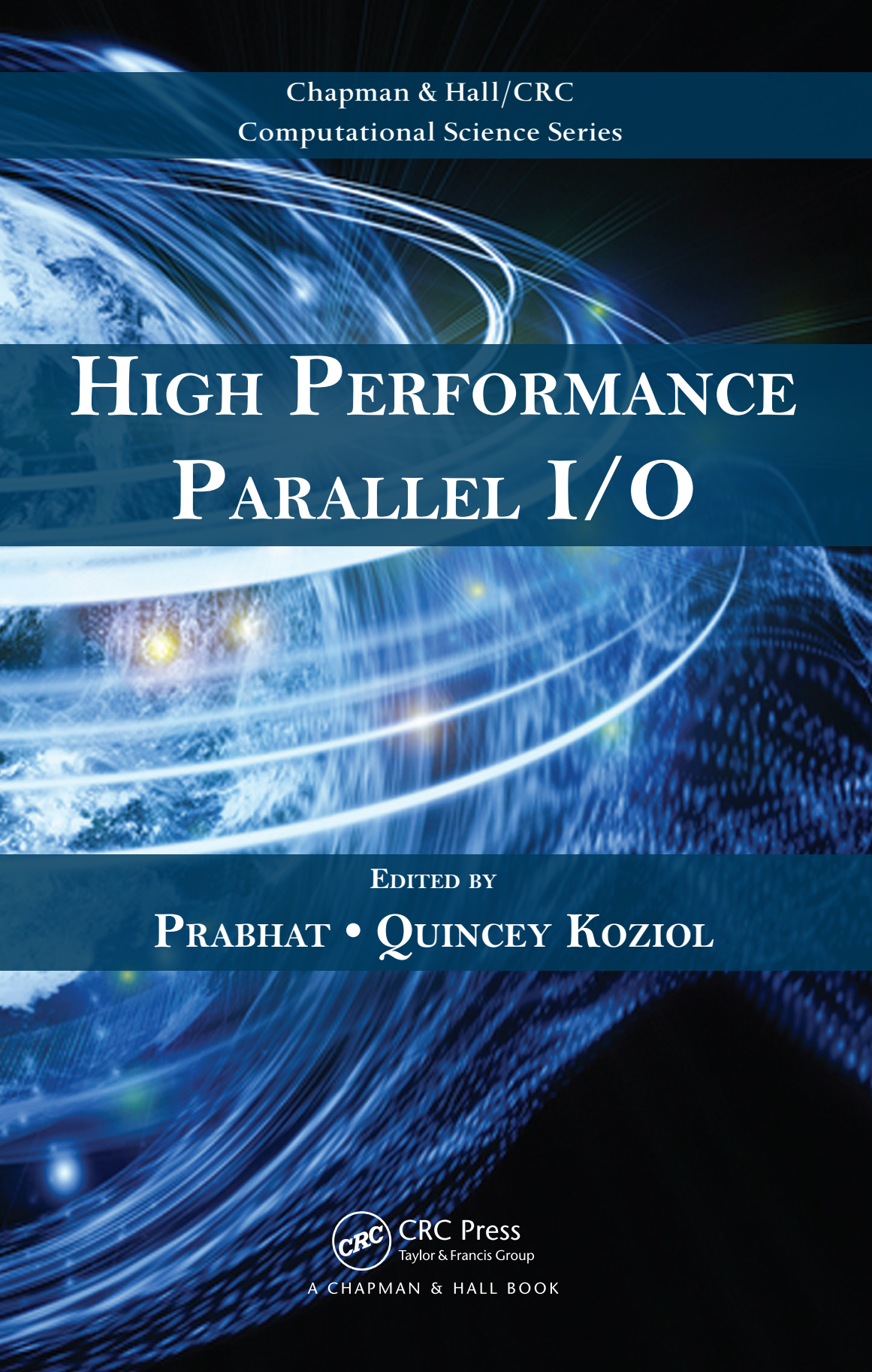
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Foreword

In the age of ever increasing emphasis on "big data" the topic of high performance parallel I/O should be amply covered in the literature. After all, what is the point of all the discussion of the ever increasing deluge of data without an understanding of how all the data are read and written quickly and efficiently? Yet, curiously a search on books on parallel I/O reveals that more than a decade has passed since any attempt has been made to summarize the state of our knowledge about high performance parallel I/O in the form of book for the High Performance Computing (HPC) community.

Prabhat and Quincey Koziol have made a significant accomplishment by editing this book on "High Performance Parallel I/O". This book is indeed remarkable since there has been so much progress in technology, software, and tools for parallel I/O in the last decade, but documenting this progress has been notably absent. I/O is often the bottleneck to achieving the best possible performance in HPC, but its treatment and discussion are quite frequently secondary to the discussion of CPU performance. The authors have set out to address this deficiency, and succeeded admirably. Their text provides a useful overview of an area of rapid development that is currently not represented in any book.

An important distinction of the current book is that is has been edited by practitioners in the field. Both editors and most of the chapter authors have been involved hands-on in developing software for parallel I/O as well as porting and optimizing scientific applications on large scale parallel I/O system. This practical experience has led the editors to direct their selection of topics for the book towards a highly usable set of themes for the individual book sections: an overview of parallel I/O system as currently implemented in leading HPC centers, a survey of file systems and I/O libraries currently in use, and a selection of case studies, augmented by a description of tools for parallel I/O. The individual chapters are contributed by the leading experts in the field. Thus the book will be a handy reference for applications developer as well as for computer center managers, who want to know about the state-of-the-art in parallel I/O.

In the last twenty years high performance computing has seen many dramatic developments. In the early 1990s computing technology made a dramatic transition to MPPs using commodity hardware and the MPI programming model. This transition and the new parallel model for HPC solidified in the early 2000s. Essentially this model has remained the same until now, while

at the same time increasing performance by a factor of one million from the Gigaflops to the Petaflops level. Today were are close to yet another transformation of the HPC field as GPUs and accelerators become integrated, while the amount of parallelism seems to be ever increasing and the field is moving towards Exaflops level performance.

In this context of a potential rapid transformation of the high performance computing field, the book by Prabhat and Koziol arrives at exactly the right time. It succeeds perfectly and for the first time provides a survey of the significant accomplishments in file systems, libraries, and tools that have been developed for about a decade. These developments have now reached a state of relative maturity, and are ripe for a treatment in book format. Simultaneously the editors combine their technology and software survey with significant application development examples in a single volume. In the last set of chapters the book previews the I/O challenges in the Exaflops era. Thus the book will provide a solid foundation for anyone who is considering using the most recent tools for developing parallel I/O intensive applications today, and be also prepared for future ExascaIe platforms. I highly recommend this timely book for computational scientists and engineers.

Horst D. Simon
Lawrence Berkeley National Laboratory
Berkeley, September 2014

Preface

Parallel I/O is an integral component of modern high performance computing (HPC). Petascale-class simulations routinely produce terabyte to petabyte-sized datasets, which need to be stored efficiently. Data-centric analysis and visualization tools rely on efficient reads to ingest and process large datasets. Both write and read operations are critical for facilitating scientific discovery and insight.

This book captures the state of the art in the field of high performance parallel I/O in the 2013–2014 timeframe. We have drawn upon insights from leading practitioners, researchers, software architects, developers, and scientists. This rich tapestry of contributions from experts sheds light on the parallel I/O ecosystem.

The book is organized in six parts. Part I is intended to give readers a window into how large-scale HPC facilities scope, configure, and operate systems, with a specific emphasis on choices of I/O hardware, middleware, and applications. Readers will find leading storage experts from the National Energy Research Scientific Computing Center (NERSC), National Center for Supercomputing Applications (NCSA), Argonne Leadership Computing Facility (ALCF), Livermore Computing Center, and Texas Advanced Computing Center (TACC) sharing their perspectives in this part of the book.

Following this, the book traverses up the I/O software stack. In Part II, we deal with the file system layer. Leading designers and architects share their insights on the design, architecture, and application of the most prominent file systems in practice today: Lustre, GPFS, OrangeFS, and OneFS. Moving further up the I/O stack in part III, we review middleware (such as MPI-IO and PLFS), and user-facing libraries (such as Parallel-NetCDF, HDF5, ADIOS and GLEAN). These chapters give insight into design decisions made by library developers, library features, and applications.

Part IV of the book delves into real-world scientific applications that utilize the parallel I/O infrastructure. Application and library developers present case studies from particle-in-cell, stochastic, finite volume, and direct numerical simulations. Careful profiling and optimization are essential for obtaining peak (and sustained) parallel I/O performance. Part V of the book presents an overview of a number of profiling and benchmarking tools used by practitioners in the field. Finally, the world of HPC is forever in flux. Part VI of the book discusses implications of current trends in HPC on parallel I/O in the exascale world.

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We would like to thank Mary Hester for an outstanding job in proofreading and editing the text. Her exemplary patience and diligence has vastly improved the quality of the book. Wes Bethel and Mike Folk encouraged us to take on this project. Randi Cohen from Taylor and Francis was very supportive of our endeavor and patient with our questions. Both of us have had a wonderful supportive environment in the Computational Research Division at Berkeley Lab, and the HDF Group, and we would like to acknowledge our colleagues. Finally, we would like to acknowledge the support and love offered by our families.

Prabhat, Quincey Koziol

April 15, 2014

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Chapter 1—Parallel I/O at HPC Facilities

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Chapter 4—Argonne Leadership Computing Facility

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Chapter 9—GPFS

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Chapter 11—OneFS

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Chapter 19—Parallel I/O for a Trillion Particle Plasma Physics Simulation

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Chapter 23—In-Transit Processing: Data Analysis Using Burst Buffers

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Chapter 24—Overview of I/O Benchmarking

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Chapter 25—TAU

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Chapter 28—Iota

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Chapter 30—Storage Models: Past, Present, and Future

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Chapter 32—Multi/Many Core

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Chapter 33—Storage Networks and Interconnects

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Part I

Parallel I/O in Practice