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Sandra Wienke · Sridutt Bhalachandra (Eds.)

# Accelerator Programming Using Directives

## 6th International Workshop, WACCPD 2019 Denver, CO, USA, November 18, 2019 Revised Selected Papers

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*Editors*
Sandra Wienke
RWTH Aachen University
Aachen, Germany

Sridutt Bhalachandra
Lawrence Berkeley National Laboratory
Berkeley, CA, USA

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# Preface

The ever-increasing heterogeneity in supercomputing applications has given rise to complex compute node architectures offering multiple, heterogeneous levels of massive parallelism. As a result, the 'X' in MPI+X demands more focus. Exploiting the maximum available parallelism out of such systems necessitates sophisticated programming approaches that can provide scalable as well as portable solutions without compromising on performance. A programmer's expectation from the scientific community is to deliver solutions that would allow maintenance of a single code base whenever possible avoiding duplicate effort.

Raising the abstraction of the code is one of the effective methodologies to reduce the burden on the programmer while improving productivity. Software abstraction-based programming models, such as OpenMP and OpenACC, have been serving this purpose over the past several years as the compiler technology steadily improves. These programming models address the 'X' component by providing programmers with high-level directive-based approaches to accelerate and port scientific applications to heterogeneous platforms.

These proceedings contain the papers accepted for presentation at the 6th Workshop on Accelerator Programming using Directives (WACCPD 2019) – http://waccpd.org/. WACCPD is one of the major forums for bringing together users, developers, and the software and tools community to share knowledge and experiences when programming emerging complex parallel computing systems.

Recent architectural trends indicate a heavy reliance of future exascale machines on accelerators for performance. Toward this end, the workshop highlighted improvements to the state of the art through the accepted papers and prompted discussion through keynotes/panels that drew the community's attention to key areas that will facilitate the transition to accelerator-based high-performance computing (HPC). The workshop aimed to showcase all aspects of heterogeneous systems discussing innovative high-level language features, lessons learned while using directives to migrate scientific legacy code to parallel processors, compilation and runtime scheduling techniques, among others.

The WACCPD 2019 workshop received 13 submissions out of which 7 were accepted to be presented at the workshop and published in these proceedings. The Program Committee of the workshop comprised 24 members spanning universities, national laboratories, and industries. Each paper received an average of five reviews.

For 2019, we encouraged all authors to add the Artifact Description (AD) to their submissions. Two additional pages were made available to authors (however without obligations) to make their code and data publicly available (e.g. on GitHub, Zenodo, Code Ocean, etc.) in support of the reproducibility initiative. As a further push, only papers with AD were considered for the Best Paper Award.

Of the 7 accepted papers, 86% had reproducibility information and these manuscripts are highlighted with an 'artifacts available' logo in this book.

The program co-chairs invited Dr. Nicholas James Wright from Lawrence Berkeley National Laboratory (LBL) to give a keynote address on "Perlmutter – A 2020 Pre-Exascale GPU-accelerated System for NERSC: Architecture and Application Performance Optimization." Dr. Nicholas J. Wright is the Perlmutter chief architect and the Advanced Technologies Group lead in the National Energy Research Scientific Computing (NERSC) center at LBL. He led the effort to optimize the architecture of the Perlmutter machine, the first NERSC platform designed to meet the needs of both large-scale simulation and data analysis from experimental facilities. Nicholas has a PhD from the University of Durham in computational chemistry and has been with NERSC since 2009.

Robert Henschel from Indiana University gave an invited talk titled "The SPEC ACCEL Benchmark – Results and Lessons Learned." Robert Henschel is the director of Research Software and Solutions at Indiana University. He is responsible for providing advanced scientific applications to researchers at Indiana University and national partners as well as providing support for computational research to the Indiana University School of Medicine. Henschel serves as the chair of the Standard Performance Evaluation Corporation (SPEC) High-Performance Group and in this role leads the development of production quality benchmarks for HPC systems. He also serves as the treasurer of the OpenACC organization. Henschel has a deep background in HPC and his research interests focus on performance analysis of parallel applications.

The workshop concluded with a panel "Convergence, Divergence, or New Approaches? – The Future of Software-Based Abstractions for Heterogeneous Supercomputing" moderated by Fernanda Foertter from NVIDIA. The panelists included:

- Christian Trott, Sandia National Laboratories, USA
- Michael Wolfe, Nvidia, USA
- Jack Deslippe, Lawrence Berkeley National Laboratory, USA
- Jeff Hammond, Intel, USA
- Johannes Doerfert, Argonne National Laboratory, USA

Based on rigorous reviews and ranking scores of all papers reviewed, the following paper won the Best Paper Award. The authors of the Best Paper Award also included reproducibility results to their paper, which the WACCPD workshop organizers had indicated as a criteria to be eligible to compete for the Best Paper Award.

- Hongzhang Shan and Zhengji Zhao from Lawrence Berkeley National Laboratory, and Marcus Wagner from Cray: "Accelerating the Performance of Modal Aerosol Module of E3SM Using OpenACC"

Emphasizing the importance of using directives for legacy scientific applications, each keynote/invited speakers, panelists, and Best Paper Award winners were given a book on "OpenACC for Programmers: Concepts & Strategies."

April 2020

Sandra Wienke
Sridutt Bhalachandra

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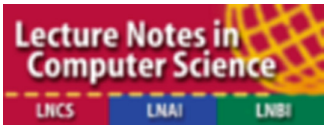

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