UCRL-JC-133372
PREPRINT

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This paper was prepared for submittal to the
Proceedings of the International Conference on Mathematics and Computation
Madrid, Spain
September 27 -30, 1999

March 2, 1999

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DRAFT March 2, 1999

Abstract

Spherical harmonic solutions are presented for the Kobayashi benchmark suite. The results were obtained with Ardra, a scalable, parallel neutron transport code developed at Lawrence Livermore National Laboratory (LLNL). The calculations were performed on the IBM ASCI Blue-Pacific computer at LLNL.

1 Introduction

A benchmark suite of three problems with simple geometry of pure absorber with large void region was proposed by Kobayashi at an OECD/NEA meeting in 1996 (Kobayashi, 1996). In this paper we present benchmark results obtained by the parallel neutron transport code Ardra. For brevity, only a short overview of the Ardra code can be given here. Further details can be found in reference (Brown, 1999).
To obtain the steady state solution, either source iteration (Richardson Iteration) or a Krylov subspace method (the Biconjugate Gradient Stabilized, BiCGSTAB, algorithm) is applied in conjunction with a sweeping algorithm, to solve the discretized system. Diffusion Synthetic Acceleration (DSA) is implemented with a parallel semicoarsening multigrid algorithm (SMG) in a highly efficient manner, which improves the convergence behavior of the algorithm significantly in optically thick regimes.
A harmonic projection method has been developed and implemented within the code system, which allows users to obtain the quality of a spherical harmonics, or $\mathrm{P_n}$ solution, while exploiting the efficiency and better parallelizability of the $\mathrm{S_n}$ method.
The Ardra code exploits concurrency with respect to all phase space variables represented by direction, position and energy. The parallel execution and interprocessor communication are performed by calls to MPI library routines, which insures portability among computing platforms. The calculations were performed on the IBM ASCI Blue-Pacific Combined Technology Refresh (CTR) computer located at LLNL (LLNL, 1998).

2 Results for the 3D Kobayashi Benchmark Suite

The benchmark suite consists of three problems, each containing a source, a void and a shield region. Problem 1 can best be described as a box in a box problem, where a source region is surrounded by a square void region which itself is embedded in a square shield region. Problems 2 and 3 represent a shield with a void duct. The first having a straight and the second a dog leg shaped duct. A pure absorber and a 50% scattering case is considered for each of the three problems. In the draft paper only results for problem 2 and 3 are given.

Table 1: Ardra Performance Data for Problem 2.

	Case i: Pure absorber P_5	Case ii: 50% scattering P_5
Iterations	21	22
Residual Norm	9.95518×10^{-6}	8.95339×10^{-6}
Number of Processors	16	16
Solution time (sec)	1738	1824

Table 2: Scalar Flux for Problem 2.

Coordinates (cm) (x, y, z)	Scalar Flux ($cm^{-3}s^{-1}$) Case i: Pure absorber P_5	Case ii: 50% scattering P_5
5, 5, 5	5.71214×10^{0}	8.10226×10^{0}
5, 15, 5	1.31748×10^{0}	2.03684×10^{0}
5, 25, 5	2.33457×10^{-1}	5.26104×10^{-1}
5, 35, 5	1.66247×10^{-1}	3.47779×10^{-1}
5, 45, 5	1.22344×10^{-1}	2.33900×10^{-1}
5, 55, 5	1.00495×10^{-1}	1.84728×10^{-1}
5, 65, 5	6.78772×10^{-2}	1.48331×10^{-1}
5, 75, 5	8.00515×10^{-2}	1.53230×10^{-1}
5, 85, 5	1.05595×10^{-1}	1.74981×10^{-1}
5, 95, 5	8.27561×10^{-2}	1.29652×10^{-1}
5, 95, 5	8.27561×10^{-2}	1.29652×10^{-1}
15, 95, 5	6.37907×10^{-5}	5.52458×10^{-3}
25, 95, 5	7.69092×10^{-4}	2.74285×10^{-3}
35, 95, 5	9.30230×10^{-5}	6.21895×10^{-4}
45, 95, 5	1.93620×10^{-5}	2.28818×10^{-4}
55, 95, 5	8.18972×10^{-6}	7.48008×10^{-5}

2.1 Problem 2

Grid spacing is $56 \times 56 \times 96$ grid cells. P_5 solutions are given in the draft paper. The solutions are obtained by the BiCGSTAB algorithm. Ardra performance data for problem 2 is summarized in Table 1. Scalar flux values at specific locations in accordance with the benchmark are given in Table 2.

2.2 Problem 3

Grid spacing is $56 \times 56 \times 96$ grid cells. P_5 and P_9 solutions are given in the draft paper. The solutions are obtained by the BiCGSTAB algorithm. Ardra performance data for problem 3 is summarized in Table 3. Scalar flux values at specific locations in accordance with the benchmark are given in Table 4.

Table 3: Ardra Performance Data for Problem 3.

	Case i: Pure absorber		Case ii: 50% scattering	
	P_5	P_9	P_5	P_9
Iterations	23	21	23	20
Residual Norm	9.28900×10^{-6}	9.02461×10^{-6}	9.88858×10^{-6}	9.3770×10^{-6}
Number of Processors	16	32	16	32
Solution time (sec)	1903	4869	1908	4659

Table 4: Scalar Flux for Problem 3.

Coordinates (cm) (x, y, z)	Scalar Flux ($cm^{-3}s^{-1}$) Case i: Pure absorber		Case ii: 50% scattering	
	P_5	P_9	P_5	P_9
5, 5, 5	5.71880×10^{0}	5.91263×10^{0}	8.13867×10^{0}	8.50686×10^{0}
5, 15, 5	1.35769×10^{0}	1.34628×10^{0}	2.10749×10^{0}	2.11809×10^{0}
5, 25, 5	2.92001×10^{-1}	4.89208×10^{-1}	6.21427×10^{-1}	8.72435×10^{-1}
5, 35, 5	2.09024×10^{-1}	2.22319×10^{-1}	4.17962×10^{-1}	4.42582×10^{-1}
5, 45, 5	1.87260×10^{-1}	9.97144×10^{-2}	3.38724×10^{-1}	2.29426×10^{-1}
5, 55, 5	1.20744×10^{-1}	8.53525×10^{-2}	2.23847×10^{-1}	1.76771×10^{-1}
5, 65, 5	4.40796×10^{-2}	5.40863×10^{-2}	1.14515×10^{-1}	1.20632×10^{-1}
5, 75, 5	1.63873×10^{-2}	1.26836×10^{-2}	4.38131×10^{-2}	3.53089×10^{-2}
5, 85, 5	4.68827×10^{-3}	3.33108×10^{-3}	1.42065×10^{-2}	1.08211×10^{-2}
5, 95, 5	1.31742×10^{-3}	1.12684×10^{-3}	4.37289×10^{-3}	3.57422×10^{-3}
5, 55, 5	1.20744×10^{-1}	8.53525×10^{-2}	2.23847×10^{-1}	1.76771×10^{-1}
15, 55, 5	1.36142×10^{-2}	1.52588×10^{-2}	5.61418×10^{-2}	5.74089×10^{-2}
25, 55, 5	1.76902×10^{-2}	2.18293×10^{-3}	4.15199×10^{-2}	1.92504×10^{-2}
35, 55, 5	1.43402×10^{-2}	4.39642×10^{-3}	2.88226×10^{-2}	1.46359×10^{-2}
45, 55, 5	1.21203×10^{-3}	1.53619×10^{-3}	5.77637×10^{-3}	5.70269×10^{-3}
55, 55, 5	4.29373×10^{-4}	3.87870×10^{-4}	2.03344×10^{-3}	1.60342×10^{-3}
5, 95, 35	3.00848×10^{-5}	2.91100×10^{-5}	3.49853×10^{-4}	3.34973×10^{-4}
15, 95, 35	2.66109×10^{-5}	2.76550×10^{-5}	2.83663×10^{-4}	2.86297×10^{-4}
25, 95, 35	5.32241×10^{-6}	1.24514×10^{-5}	1.81070×10^{-4}	1.93682×10^{-4}
35, 95, 35	5.47851×10^{-5}	3.70676×10^{-5}	3.27109×10^{-4}	2.63865×10^{-4}
45, 95, 35	7.47407×10^{-6}	7.39978×10^{-6}	1.02811×10^{-4}	1.07957×10^{-4}
55, 95, 35	4.421447×10^{-7}	-8.86691×10^{-8}	3.84001×10^{-5}	4.10805×10^{-5}

3 Conclusions

Solutions, obtained with the parallel transport code Ardra are presented for the Kobayashi benchmark suite. While only a limited number of results are presented in this draft version of the paper, we expect to present a more comprehensive study of the benchmarks in the full paper which will include results for problem 1.

Acknowledgments

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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