Office of Science
U.S. DEPARTMENT OF ENERGY

Advanced Scientific Computing Research
FY 2003 Accomplishment

The Performance Evaluation Research Center (PERC)

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Summary

The Performance Evaluation Research Center (PERC) project is developing a science for understanding and improving the performance of scientific application codes on large-scale computer systems. PERC integrates several new efforts in high performance computing, and is forging alliances with several other SciDAC scientific projects. PERC made major strides in FY03. Most importantly, we developed methods for performance modeling, applied it to understand the performance of some important applications, and significantly improved the performance of applications in central areas of the Office of Science's mission. We also published several papers at major conferences and instructed users in how our tools enable understanding and improvement of their applications' performance.

The PERC project made FY03 advancements in the following areas:

- Understanding the key factors in scientific codes that affect performance;
- Understanding the key factors in computer systems that affect performance;
- Developing models that accurately predict performance of codes on systems;
- Developing an enabling infrastructure of tools for performance monitoring, modeling and optimization;
- Validating these ideas and infrastructure via close collaboration with DOE SciDAC projects and other scientists;
- Transferring this technology to scientists.

PERC research has been motivated by the belief that overall performance (namely wall-clock execution time) is dominated by how well a scientific code exploits the entire memory hierarchy of a machine. Hence, a science of performance must analyze performance phenomena from the register and CPU level up to the scale of the interprocessor network and beyond.

PERC focuses on four thrusts:

- Application and system benchmarking;
- Performance analysis tools;
- Performance modeling and analysis; and
- Performance optimization.

PERC benchmarking activities target both application characterization and machine measurement. PERC has developed effective low-level benchmark programs that accurately measure multi-level memory system performance. PERC has also adapted large-scale scientific applications for use as high-level benchmarks. These benchmark codes permit PERC researchers to compare systems and analyze performance at multiple levels.

PERC performance analysis tools span the spectrum from low-level infrastructure to high-level end-user tools. In FY03, PERC researchers improved the PAPI hardware performance monitoring infrastructure being developed at the University of Tennessee and the dynamic instrumentation API being developed at the University of Maryland and integrated these technologies with end-user tools. End-user tool efforts include the SvPablo toolkit under development at the University of Illinois Urbana-Champaign, the Sigma tool for cache measurement from the University of Maryland with participation by IBM Research, and the MetaSim toolkit for identifying an application's memory

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access patterns under development at the San Diego Supercomputer Center.

PERC researchers are pursuing several distinct performance modeling and analysis strategies, including machine signatures, application signatures, statistical modeling and performance bound analysis. A highlight of this activity during FY03 has been the development of an infrastructure of low-level benchmarks, high-level tools and a "convolution" methodology. The infrastructure has been applied to form performance accurate models of several large-scale scientific codes including POP (Parallel Ocean Program), NLOM (Navy Land Ocean Model), and Cobalt60 (CFD application). The models explain performance differences on several current HPC machines and predict the performance improvement of these applications on future architectures.

PERC researchers have established contacts with a number of SciDAC application projects and other scientists doing large-scale computations under sponsorship of DoE/SC, including the following::

1. *TSI Supernova project*: In collaboration with TSI researchers, PERC has extensively analyzed the astrophysics codes EVH1 and Agile-Boltztran using SvPablo and PAPI. Removal of certain performance bottlenecks resulted in significantly better performance.

2. *Accelerator S&T project*: PERC is analyzing the Standard Template Library, which is used heavily in these C++ codes and has identified a number of optimizations for one key code.

3. *Lattice Gauge Theory project*: PERC researchers have analyzed the performance of the MILC code, an important lattice gauge QCD code. In particular, the communication performance has been studied on a Pentium-4 cluster system.

4. *Community Climate System Model project*: PERC has studied the CAM benchmark program in detail, motivating changes that have significantly improved the parallel scalability of CAM. Baseline performance figures for the POP ocean model have been generated as well.

5. *Wave-Plasma Interaction Fusion project*: PERC has benchmarked, analyzed and modeled the performance of the AORSA3D application code. Results?

6. *Terascale Optimal PDE Solvers project*: PERC researchers have analyzed and optimized several codes, resulting in reductions both in floating-point operation counts and overall runtime for a mesh smoothing code. In addition, we have developed a performance bound model for TOPS codes, including a 2D/3D radiation transport code.

For further information on this subject contact:

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Paul D Hovland
Comment: The mesh smoothing app is actually a TSTT/TOPS joint project. We could either mention both ISICs explicitly or be a little vague. -- PDH

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Paul D Hovland
Comment: Algorithm? Presumedly, this refers to some part of the STL.

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