Title: Novel Fundamental in Strategic Computing

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Submitted to: DOE Office of Scientific and Technical Information (OSTI)
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Novel Fundamentals in Strategic Computing

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Abstract

This is the final report of an initially funded for three-year, Laboratory-Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). The funding was zeroed after the first year at the time of the 6% to 4% reduction in LDRD funding. All the information in this report describes the work done in this single year of research. We carried out research in common component architectures, performance modeling and models of computations related to deep memory hierarchies. The goal of this first year was to create to basis for the integrated approach to the analysis and modeling of the software-hardware-algorithms realities of computing driven by non-scientific applications.

Importance to LANL's Science and Technology Base and National R&D Needs

Computational science is of paramount strategic importance at the Laboratory. The computational needs of programs such as ASCI require computer systems and software of unprecedented scale and complexity. However, the computing landscape of tomorrow is likely to be very different. The development of microprocessors, networks, software and algorithms is no longer driven to the needs of scientific computing. In fact, applications such as multimedia, web-applications and data mining are the new driver apps for computing systems and networks. Given a COTS approach to building extreme-scale hardware and software systems, the question arises as to whether the COTS of tomorrow will allow us to achieve the computing goals at the Laboratory. This project intended to address many of the inter-related areas in answering this question.

Scientific Approach and Accomplishments

Software, hardware, and algorithms are continually increasing in size and/or complexity, resulting in large, compositional systems. They are engineered by systematically combining smaller, well-understood components. Despite this trend, the techniques for building such systems are poorly understood. Our project adds insight into compositional software, hardware, and algorithms.

This year we developed a high-level design and implemented a prototype of a component architecture for high-performance scientific applications. This concrete implementation
will allow us to experiment and empirically evaluate techniques and abstractions, as well as provide a vehicle for building actual multicomponent applications. In collaboration with scientists from academia and other national laboratories, we made significant progress in formulating an interoperability standard for high-performance computing component architectures: the Common Component Architecture.

We carried out extensive research on existing memory models of computation. From a theoretical/practical standpoint we have identified the models of Alpern et al. and Vitter et al. as suitable for future exploration. We also studied different memory-efficient algorithms for linear-relaxation-type problems that have been proposed in the literature. As a step toward building a robust complexity theory for memory-centric computation, we have begun identifying generic algebraic specifications that can be used to represent large classes of seemingly unrelated problems in the same framework. We have also begun to identify necessary characteristics of transformations (reductions) that can be used to establish equivalence classes of problems under a given computational model.

We initiated a performance evaluation of commodity processor architectures with the intention of studying their performance on ASCI and “driver” (multimedia, web, and data-mining) applications. We then created a preliminary set of multimedia benchmark codes, which cover a variety of mass-market applications. We have developed a novel hardware-counter-based instruction-level analysis technique that is suited for characterizing multimedia and other commercial applications. We also proposed a methodology for performance modeling and prediction of large-scale scientific applications, which we then used to characterize one major ASCI application.

**Publications**


