

INNOVATIVE COMPUTING
LABORATORY

2004-2005 REPORT



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The Innovative Computing Laboratory aspires to be a world leader in enabling technologies and software for scientific computing. Our vision is to provide high performance tools to tackle science's most challenging problems and to play a major role in the development of standards for scientific computing in general.

BACKGROUND

In the Fall of 1989, Dr. Jack Dongarra came to the University of Tennessee (UT) from Argonne National Laboratory (ANL) and founded ICL. Dr. Dongarra was given a dual appointment as Distinguished Professor in the Computer Science Department at the university and as Distinguished Scientist at Oak Ridge National Laboratory (ORNL). This dual position was established by the UT/ORNL Science Alliance, Tennessee's oldest and largest Center of Excellence, as a means for attracting top research scientists from around the country and the world to visit the university and collaborate. As a result, many post-doctoral researchers and professors from multi-disciplines such as mathematics, geology, chemistry, etc. found their way to UT. Many of these scientists remained as post-doctoral researchers and worked with Dr. Dongarra to form the foundation for attracting other researchers and top graduate students. Below is a list of some of the researchers who have been instrumental in helping Dr. Dongarra with the establishment and growth of ICL:

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THE UNIVERSITY OF CALIFORNIA, DAVIS

Adam Beguelin

TURVEO

Henri Casanova

THE UNIVERSITY OF CALIFORNIA, SAN DIEGO

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LAWRENCE LIVERMORE NATIONAL LABORATORY

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MANCHESTER UNIVERSITY, ENGLAND

Sathish Vadhiyar

INDIAN INSTITUTE OF SCIENCE (IISc), INDIA

Through interactions with colleagues at Rice University, ICL became an integral part of the Center for Research on Parallel Computation (CRPC), a National Science Foundation (NSF) Science and Technology Center established in 1989 and lead by Rice University. CRPC worked to make parallel computation accessible to industry, government, and academia and to educate a new generation of

technical professionals. During the 1990s, ICL worked on a number of efforts that have since become part of the basic fabric of scientific computing around the world. The basic technologies that our research has produced include ATLAS, BLAS, LAPACK, ScaLAPACK, PVM, MPI, Netlib, RIB, and the NHSE. These successes are continuing along with current ICL efforts such as Active Netlib, NetBuild, PAPI, FT-MPI, NetSolve/GridSolve, SANS-Effort, vGrADS, the TOP500 and the HPC Challenge suite of benchmarks. Recognition of our successes over the past decade has come in many forms, including four R&D 100 awards, starting with PVM in 1994, ATLAS and NetSolve in 1999, and then PAPI in 2001.



CLAXTON BUILDING, HOME OF ICL

PROFILE

Entering its 16th year, ICL is located at the heart of the University of Tennessee campus in Knoxville. In this short time, ICL continues to establish itself as one of the most respected academic, enabling technology research laboratories in the world.

Our many contributions to technological discovery in the HPC community, as well as at UT, underscore our commitment to remain at the forefront of enabling technology research. Recognition for our efforts and the impact our efforts have had, and continue to have, on the goals of the University of Tennessee are reflected by the Chancellor of the Knoxville campus, Dr. Loren Crabtree;

“The Innovative Computing Laboratory of the Computer Science Department continues to be a tremendous asset to our university. ICL is expected to enhance its leadership role in enabling technology research initiatives, especially as the relationship between the University of Tennessee and nearby Oak Ridge National Laboratory strengthens over the coming years. While we continue our focus here at UT on establishing our position as a premier research university, our ability to attract and retain top research talent is very important. Under the leadership of Dr. Jack Dongarra, the staff and students of ICL have consistently demonstrated the skill and effort that embody the university’s approach and commitment to outstanding research. ICL’s accomplishments over the past decade have helped propel our university into the 21st century, and we are grateful for the impact their contributions continue to have, not only on our university, but also on the national research agenda.”

“ICL’s accomplishments over the past decade have helped propel our university into the 21st century...”

- Dr. Loren Crabtree, Chancellor of UTK

ICL QUICK STATS

ESTABLISHED 1989
ANNUAL BUDGET ~\$5 MILLION

ICL is celebrating 15 years of leadership in enabling technologies for high performance computing. Looking back over the 15-year period, the evolution and growth of the technology for computing has been truly astonishing. In an environment where technology changes every 18 months, ICL cannot afford to stand still. In 1989 the speed of a supercomputer was measured in gigaflops and in gigabytes. Today our measures are teraflops for speed and terabytes for memory, a thousand-fold increase over the standards of a decade ago. The research that ICL has undertaken in the past decade has followed a natural progression and growth from our original tread of numerical linear algebra to performance evaluation, to software repositories, and to distributed computing. Much has been accomplished since the early days of ICL and much remains to be done.



The Innovative Computing Laboratory is addressing some of the most important computational scientific issues of our time. Our plans for the future are founded on our accomplishments as well as our vision. That vision challenges us to be a world leader in enabling technologies and software for scientific computing. We have been and will continue to be providers of high performance tools to tackle science's most challenging problems and to play a major role in the development of standards for scientific computing in general.

We are building from a firm foundation. Over the past 15 years, we have developed robust research programs, attracted some of the best and brightest students and researchers, and created leading-edge research programs. The ICL staff's ongoing ability to apply the latest technologies to provide advanced services and solutions for the scientific computing community underscores the ICL's leadership role. Standards and efforts such as PVM, MPI, LAPACK, ScaLAPACK, BLAS, ATLAS,

This is an extraordinary time to be involved
in high performance computing.

Netlib, NHSE, Top500, and the Linpack Benchmark have all left their mark on the scientific community. We can be proud of the recognition and use our tools receive. We are continuing these efforts with PAPI, NetSolve, RIB, the Top100 Clusters, Harness, Active Netlib, Self-Adapting Numerical Software Effort (SANS-Effort), the High Performance Computing Challenge (HPCC), FT-MPI, and Open-MPI as well as other innovative computing projects.

We continue to grow in terms of the resources we have at our disposal. We have ongoing efforts to strengthen our organization and to ensure the proper balance and integration of research and projects. The pace of change will continue to accelerate in the coming years.

This is an extraordinary time to be involved in high performance computing. During these exciting times, I am grateful to our sponsors for their continued endorsement of our efforts. My special thanks and congratulations go to the ICL staff and students for their skill, dedication, and tireless efforts in making the ICL one of the best centers for enabling technology in the world.

Jack Dongarra
DIRECTOR OF THE INNOVATIVE COMPUTING LABORATORY

Keeping pace with the changes in the computational landscape requires adaptability and our research reflects this. As computational demands continue to increase, so will the opportunities for innovative, engaging research in enabling technology. These demands over the past several years have not only allowed ICL to grow, but have also allowed us to demonstrate the range and diversity of the research performed by our staff and students. Our large and wide-ranging portfolio of research projects has evolved over the course of more than a decade, beginning from a narrow but solid foundation. In 2004-2005, we will support or participate in more than 17 significant projects.

Numerical linear algebra, specifically the numerical libraries that encode its use in software, has been the foundation of our work since 1989. But because of the unique demands for enabling technology in the computational science community over the past decade, we expanded our research to include work in high performance and distributed computing. Our efforts in these areas fostered the need for expertise in performance evaluation and benchmarking for high-end computers. The enormous investments by both government and private industry in high performance computing have made our ability to do research in this area correspondingly important. Finally, as a by-product of a long tradition of delivering high quality software produced from our research, we have helped to lead the movement to build robust, comprehensive, and well-organized software repositories.

The challenges facing the scientific community in the 21st century will continue to scale as the demands for computational technology increase. As the world learns to harness enormous computing power to efficiently perform such tasks as graphical simulations and analysis of massive data sets, ICL faces increasing pressure to stretch the boundaries of discovery. Incredible growth and change in parallel computing technology and the demands placed on such technology by government and private business consistently challenge us to apply expert-level understanding to each of our research efforts.

On the following pages, we describe our research efforts in each of our four main areas of focus - numerical libraries, high performance distributed computing, performance evaluation and benchmarking, and software repositories. Our achievements in each of these areas over the past year are also highlighted.

ICL QUICK STATS

ACTIVE PROJECTS 17
R&D 100 AWARDS 4

ACKNOWLEDGEMENT

Evidence of the perceived value of our work and the importance of our research is apparent in the range of agencies and organizations that have funded, and continue to fund, our efforts. The main source of support has been federal agencies that are charged with investing the nation's computational research funding: the National Science Foundation (NSF), Department of Energy (DOE), Department of Defense (DoD), the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research (ONR), and the National Institute of Health (NIH). However, strong support from private industry has also played a significant role. Some organizations have targeted specific ICL projects. But others have made contributions to our work that are more general and open-ended. We gratefully acknowledge the following for their generosity and their significance to our success:



OVERVIEW

Scientific computing relies heavily on Linear algebra operations. Sparse linear systems and eigenvalue calculations come from, among others, applications that involve partial differential equations, and dense operations arise from boundary element methods, quantum scattering, etc. ICL has long been a leader in producing standards, algorithms, and software for numerical linear algebra. In collaboration with other researchers and with industry, we have led efforts to standardize and adopt the Basic Linear Algebra Subprograms (BLAS) through the BLAS Technical Forum and the development of libraries such as LINPACK, LAPACK, and ScaLAPACK. These efforts have been widely adopted by the scientific community, as well as by the computer industry through inclusion in commercial standard numerical libraries.

These earlier libraries focus primarily on algorithmic innovations, moving performance considerations to the kernel level. ICL evolved such work by releasing the Automatically Tuned Linear Algebra Software (ATLAS) package, which delivers an optimized library in a fraction of the time of hand coding, and which is competitive with vendor-supplied libraries. ATLAS has been widely accepted, having been included in both the MATLAB and OCTAVE linear algebra packages, as well as SciPy – an extension of the Python language for scientific computing. In addition to our activities in dense algebra libraries, we have been involved in sparse linear algebra efforts, releasing a performance benchmark for iterative methods.

More recently, we have applied considerable effort toward Self-Adapting Numerical Software (SANS) systems, which aim to relieve the user of several levels of decision making in the process

of realizing optimally performing numerical software. Such systems adapt the realization process to the computational environment on several levels, including the kernel, network, and algorithmic levels. SANS, which is a collaborative effort, comprises work in kernel level optimization (ATLAS and Accels) along with our work in network level adaptation (LAPACK for Clusters - LFC) and an algorithmic decision-making component (Self-Adapting Large-scale Solver Architecture - SALSA). Combined, these levels constitute a dynamic environment where a user's problem gets solved by an algorithm that is chosen based on characteristics of the input data, scheduled over the current state of the computational grid, and then executed with kernels optimally suited to the processors used and, in the sparse case, tailored to the data.

Our LFC project merges the ease of use of LAPACK with the parallel processing capabilities of ScaLAPACK. LFC is a self-contained package with built-in knowledge of how to run linear algebra software on a cluster. Users are responsible for stating their numerical problems but can assume they are working in a serial environment. The LFC middleware assesses the possibility of solving the problem faster in parallel on some subset of the available resources, based on information describing the state of the system. The user's problem is distributed over the selected processors with a load distribution dependent on the machine loads and relative capabilities, the problem is executed in parallel, and the solution is returned to the user. Experimental results compare favorably with the performance obtained by an expert user in the same environment.

RECENT RESEARCH

We are making considerable progress in the development of the SALSAs system for heuristic decision making in the context of linear and nonlinear system solving. The software functions as an increasingly powerful testbed for iterative linear system solvers, using the available methods from the PETSc library, and attached packages such as HyPre. For internal use in the system, as well as for external use in matrix libraries or generally for communication between numerical software components, we have proposed a metadata standard for matrix data that formalizes the matrix characteristics we analyze. We have released a library that defines this standard through an API and an XML file format. A collection of analysis modules for generating characteristics of user input data should be released by Q1 2005. We also are continuing research on identifying statistical techniques and tools for building heuristics.

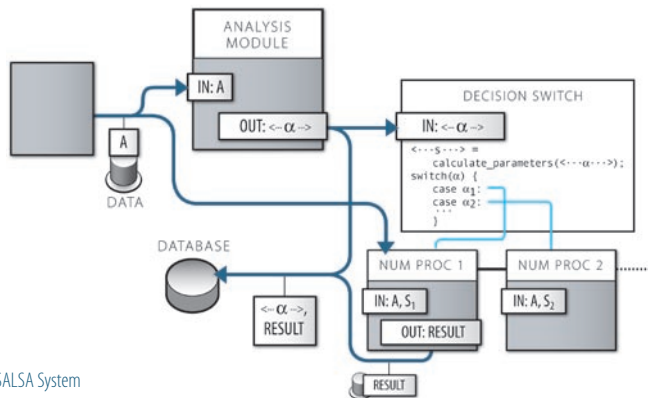
configuration infrastructure of the new version extensively contributes to the robustness of the package and helps with deployment in mixed-compiler environments. Improved compatibility with ScaLAPACK and all of its underlying technologies adds functionality necessary to implement important parts of a computational server based on LFC. The server may be controlled from scripting languages like Mathematica, Matlab, and Python which combines the performance of ScaLAPACK, the automatic scheduling of LFC, and the ease of expression of the scripting language.

We are continuing work on kernel optimization in the spirit of the ATLAS project. Our current project Accels (ACcelerated Compressed-storage Elements for Linear equation Solvers) is aimed at sparse matrix-vector operations that occur mostly in iterative solvers. An optimization strategy comprised of an

installation phase, determining machine characteristics, and a dynamic phase, determining data characteristics, has been shown to give substantial performance improvements

For the nano-physics community, we have begun to study certain eigenvalue problems where interior eigenvalues are needed, which are degenerate and close to a gap in the spectrum with known location. This problem

poses a considerable challenge to traditional methods, and we are investigating different approaches to solving it.



The SALSAs System

In mid-2004, a new version of LFC was released which added support for single precision data to the existing decompositional solvers; LU, Cholesky, and QR. The reworked

OVERVIEW

Distributed computing provides a fundamental platform for building modern High Performance Applications. ICL's involvement in distributed computing spans more than a decade, producing such successful systems as the Parallel Virtual Machine (PVM) jointly with Oak Ridge National Laboratory. Currently, we are involved in three levels of distributed computing from high level problem solving environments such as NetSolve and VGrADS, through middleware technologies such as GridRPC and FT-MPI (Fault Tolerant Message Passing Interface) to low level systems such as HARNES (Heterogeneous Adaptable Reconfigurable Networked Systems).

One of our flagship research projects in distributed computing is NetSolve and it has been the basis for a number of complementary efforts such as GridSolve and GridRPC. Netsolve is an RPC style Grid middleware that allows the domain scientist to combine the power of distributed and hardware and software, and utilize them from within familiar general purpose Scientific Computing Environments (SCEs) such as Matlab and Mathematica. A Grid based version of NetSolve, which utilizes Grid services such as Condor, Network Weather Service (NWS), and the Internet Backplane Protocol (IBP) has also been developed known as GridSolve. A logical extension to this work is the building of a standardized RPC API for general Grid usage. ICL together with the Global Grid Forum are well advanced in developing such a standard known as GridRPC. Furthering inter-institutional collaboration on developing Grid applications is managed under the Virtual Grid Application Development Software (VGrADS) project led by Rice University. VGrADS is a leading edge research project that includes more than a dozen top researchers from seven different universities and aims to address the key scientific and technical problems that must be solved in order to make it relatively easy to develop Grid applications for real problems and to tune those applications for high performance.

Another project, called the Fault Tolerant Message Passing Interface (FT-MPI), provides advanced support for fault-tolerant applications that is crucial for large, long running simulations. Currently, fault tolerant

applications cannot be built with standard MPI libraries because MPI is unable to handle failures gracefully. Under FT-MPI, applications have flexible API level control over how failures are handled, allowing message passing applications to be built that can survive node failures without the need to continuously make expensive state and checkpoint dumps to disk. This in turn makes FT-MPI an ideal platform for the development of algorithms that can adapt to failures, which is currently not possible with other implementations of MPI. As well as being fault tolerant, FT-MPI is also a leading edge open source MPI implementation. The performance of FT-MPI is comparable to other leading open source MPI implementations.

Our Grid computing research is supported by the Scalable Intracampus Research Grid (SInRG), described in more detail in the Hardware section (p. 23), Some of the grid middleware developed as a part of the SInRG project (and described here) is now widely recognized in the national and international grid computing communities.

RECENT RESEARCH

The latest release of NetSolve, version 2.0, includes an implementation of the GridRPC API. NetSolve/ GridSolve-2.0 is now an integral part of NSF Middleware Initiative (NMI). NetSolve and the Internet Backplane Protocol, two SInRG middlewares, have been combined into partner applications now supporting researchers in Computational Ecology, Medical Imaging, Computational Combinatorics, as well as Statistical Parametric Mapping (SPM) and remote users of ATLSS (Across Trophic Level System Simulation) developed here at UT.

NetSolve's functionality has been extended through new enhancements to address various limitations. Some examples of these enhancements include task farming, request sequencing, and security. However, some desirable enhancements cannot be easily implemented within the current NetSolve framework. These new requirements, such as client scheduling and parallel machine support coupled with the requirements for the

original NetSolve system, will form the basis for the next generation of NetSolve, which will involve redesigning the framework from the ground up.

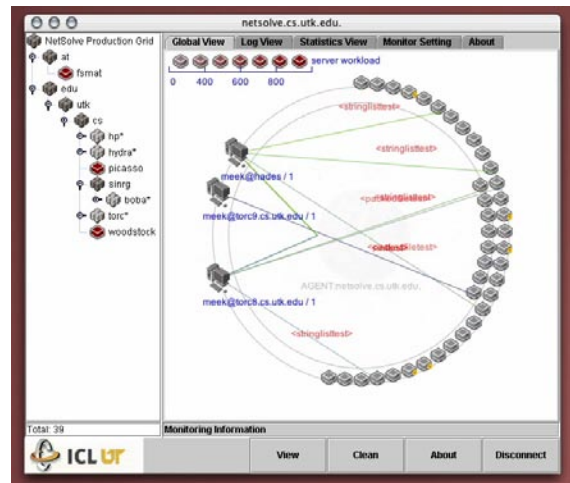
The overall goal of this next generation of NetSolve, dubbed NetSolve-E, is to address three general problems: ease of use, interoperability, and scalability. To improve the ease of use, we have streamlined the process of integrating user code into a NetSolve server. Interoperability encompasses several facets, including better handling of different network topologies, better support for parallel libraries and parallel architectures, and better interaction with other Grid computing systems such as Globus and Ninf. Scalability in the context used here means ensuring that system performance does not degrade as a result of adding components to the NetSolve system.

In addition, development has continued on visPerf, a grid monitoring application that simplifies NetSolve by visualizing the current grid activity. To visualize the grid activity, the client application connects to a sensor. The sensor monitors the NetSolve agent log file and sends current events to the client that then displays a graphical representation of each event and records it in a logging interface. These features plus others allow NetSolve users to easily understand the status of the NetSolve grid.

The VGrADS project is building on the successes and lessons of the recently completed GrADS (Grid Application Development Software) project, which created a prototype Grid application preparation and execution system. This system was aware of Grid resources, and could prepare, schedule, launch, monitor and even migrate certain MPI based Grid applications. The VGrADS project is currently defining “vgrids”, an abstraction of Grid resources that could be used to simplify many of the tasks involved in deploying Grid applications. We are benchmarking and monitoring Grid resources to allow them to be classified into the appropriate virtual resource classes and we are examining relevant applications to ensure that our vgrid classes meet the needs of the applications.

FT-MPI, supporting the full MPI 1.2 specification, was released at SuperComputing 2003. Since the release of the FT-MPI runtime library, system level software and

The VisPerf NetSolve monitor showing grid activity



environment management have been both enhanced and improved. This is in addition to the creation of a number of new fault tolerant numeric methods and application examples. Changes to the FT-MPI library include the addition of the full C++ binding and a number of the MPI-2 library calls including language inter-operation, ‘info’ objects, extended collectives, etc. The FT-MPI runtime has undergone a number of major performance improvements in the areas of buffer management and collective communication performance. The buffer management system has been altered so that it is now driven by the capabilities of the underlying communications driver. This allows it to better overlap data conversion and communication. The collective communication library has been enhanced with a number of new topologies as well as a larger number of segmented communication patterns for large message handling together with better collective vector optimizations for all patterns.

Some of the runtime and system management features of FT-MPI are currently being applied to a new open source MPI implementation known as “Open MPI”. This is a new collaborative project between LANL, Indiana University, ICL, Ohio State University and HLRS Stuttgart, Germany. In a later stage of integration the fault tolerant mechanisms of FT-MPI will be added to Open MPI as a user selectable module.

OVERVIEW

ICL continues to play a leadership role in benchmarking and performance evaluation efforts that measure and report performance on high performance computing (HPC) machines. Through development of many benchmark codes, we have been able to remain at the forefront of performance evaluation research. One such code, the LINPACK benchmark, is a numerically intensive test for solving a dense system of linear equations and has been used for years to measure the floating-point performance of computers. Performance on this benchmark is the basis of the semi-annual TOP500 list that ranks the fastest 500 computers in the world.

Our research staff has also led the development of a portable high-performance implementation of the LINPACK benchmark for distributed memory parallel computers, called High Performance LINPACK, or HPL. HPL contains many possible variants for the various operations, in order to provide the user with the opportunity of experimentally determining an optimal set of parameters for a given machine configuration. State-of-the-art algorithms are used, including recursive panel factorization with pivot search and column broadcast combined and a bandwidth-reducing swap broadcast algorithm.

To examine the performance of HPC architectures using kernels with more challenging memory access patterns than HPL, the HPC Challenge (HPCC) project is developing a suite of benchmarks that bound the performance of many real applications as a function of memory access characteristics. HPCC provides a single program to download and run with a simple input file, similar to HPL. However, in addition to HPL, HPCC currently includes several other benchmarks for measuring sustainable memory bandwidth, the rate of random memory updates, and the latency and bandwidth of a number of communication patterns.

Our research staff has also helped develop the SparseBench benchmark suite for iterative methods on sparse matrices. Solution of sparse linear systems, such as those derived from Partial Differential Equations (PDEs), form an important problem area in numerical analysis as well as being the basis for computational

problems in a number of application areas, including computational fluid dynamics and structural mechanics. Unlike in the case of dense linear systems, solution of sparse systems does not entail much reuse of data. Thus, algorithms for sparse matrices will be more bound by memory speed than by processor speed.

In addition to developing benchmarks, our research staff is actively involved in the development of performance evaluation tools and methodologies. As a basis for collection of accurate and relevant performance data, we have developed a portable library interface for access to hardware performance counters on most modern microprocessors. The interface, called the Performance API, or PAPI, not only provides a standard set of routines for accessing counter data, but also defines a common set of performance metrics considered relevant and useful for application performance tuning. PAPI provides two interfaces to the underlying counter hardware; a simple, high level interface for the acquisition of simple measurements and a fully programmable, low level interface directed towards application and tool developers with more sophisticated needs.

The KOJAK project, a joint project with the Central Institute for Applied Mathematics at the Research Centre Juelich, is developing a set of interoperable tool components for the performance analysis of parallel applications written in OpenMP and/or MPI, focusing on automatic techniques to transform performance data into a high-level view of performance behavior. The KOJAK analysis process consists of semi-automated automatic multi-level instrumentation of the user application followed by automatic analysis of the generated performance data. Mechanisms are provided for collecting event trace files and call-graph profiles and for supplementing both with the collection of relevant hardware counter data using PAPI. Trace file output may then be analyzed automatically using the EXPERT analyzer and CUBE display tool. EPILOG trace files generated by KOJAK can also be converted to Vampirtrace files for viewing by the widely used commercial Vampir MPI analysis tool.

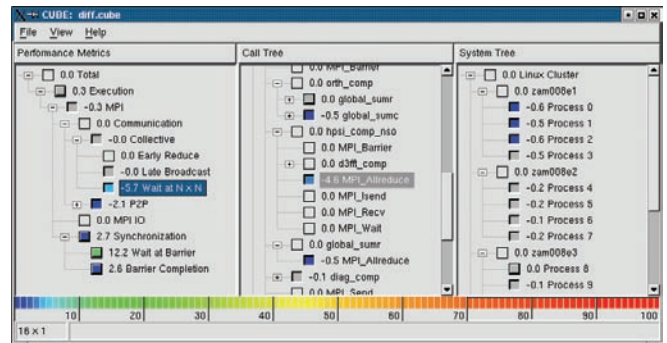
RECENT RESEARCH

Since its introduction at SC '03, the HPCC project has added two new benchmarks to the suite; DGEMM for measuring the floating point rate of execution of double precision real matrix-matrix multiplication, and FFTE for measuring the floating point rate of execution of double precision complex one-dimensional Discrete Fourier Transform (DFT). A Web interface has been developed for submitting and viewing HPCC benchmark results. Results have been collected for a number of HPC machines, including Cray X1, SGI Altix clusters, IBM p690 clusters, AMD Linux clusters, Intel Xeon Linux clusters, and Intel Itanium Linux clusters. The results table shows the performance for each machine on each of the seven component HPC Challenge benchmark codes.

In the past year we have continued the development of PAPI, the Performance API. PAPI 3.0, a major rewrite of the PAPI library, has been released. PAPI 3 provides a streamlined interface with significantly reduced overheads. It supports multiple simultaneous event overflows and statistical profiling, and has enhanced support for performance events native to specific architectures. PAPI 3 now supports most HPC architectures, including IBM POWER 3 and 4, SGI Origin, Itanium 1 and 2; Pentium III and IV, AMD Opteron, and Cray X1. The PAPI team has developed the *papiex* command-line utility to provide an easy-to-use tool for collecting basic performance data for serial and parallel programs. We have also developed the Dynaprof tool that enables a user to attach to and instrument a running application in order to collect a variety of performance data on-the-fly. In addition, the PAPI team has continued to work with developers of other performance tools, such as TAU (University of Oregon), SvPablo (University of Illinois), and HPCToolkit (Rice University), to incorporate support for PAPI 3.

KOJAK's EXPERT tool supports the analysis of large event traces by automatically searching them for execution patterns that indicate inefficient behavior. We have recently devised a more efficient search scheme that takes advantage of the specialization hierarchy between pattern specifications to eliminate redundant

searching. The new scheme leads to significant runtime improvement as well as to more compact pattern specification. We have also incorporated measurements for various hardware counter events, such as operation counts and cache and memory events, into the pattern analysis. The CUBE component of the project has developed a performance algebra for combining multi-experiment results that enables performance data from different executions, such as those for which different performance metrics have been collected, to be combined. The figure below shows a CUBE analysis of two versions of a nano-particle simulation. Raised reliefs indicate performance improvements, and sunken reliefs indicate performance degradations. The differences are broken down along various dimensions including metrics, call tree, and processes. The display is a specific example of CUBE's extensible support for interactive exploration of a multidimensional performance space in a scalable fashion.



CUBE display showing performance differences between two code versions.

A new version of KOJAK incorporating these and other new features has recently been released for a number of HPC platforms, including IBM POWER3/4, SGI Origin, Sun Sparc, and Linux IA-32 and IA-64 clusters, including SGI Altix clusters. Work is also underway to use this new version of KOJAK to analyze the performance of a number of large-scale scientific applications.

OVERVIEW

The creation and development in the 1980s of the Netlib repository for mathematical software and other related resources represents the cornerstone of our repository efforts. Netlib's enormous past success and benefits to HPC have been well established. As a result of such success and the ever increasing demands for software reuse generated by the proliferation of scientific computing and simulation here in the US, the National HPC Software Exchange (NHSE) was formed in the mid 1990s by several academic institutions and government agencies with the primary goal of establishing discipline-oriented software repositories that could be contributed to and maintained by experts in their respective fields. ICL was one of the academic partners called upon to participate in this national effort.

One result of the NHSE effort was the development of the Repository in a Box (RIB) toolkit, which was developed to enable the creation and interoperability of discipline-oriented, web-based software repositories, specifically the tools and applications generated by the HPC community. RIB development and enhancement continues here at ICL and has evolved to support the creation of repositories to store and share any type of digital object. The ICL staff currently maintains several domain specific software repositories built with RIB including the Parallel Tools Library (PTLib) and the High Performance Netlib (HPC-Netlib) Library. Leveraging the many advantages of RIB and drawing upon the vast Netlib resources, we continue our work of providing tools for sharing metadata and libraries through the creation of the Active Netlib project, which provides an

interactive, inquiry-based learning environment about mathematical software for undergraduate engineering students, teachers, and practicing engineers. Active Netlib utilizes NetSolve (also produced here at ICL), RIB, and Netlib and is part of the broader NSF-funded National Scientific Digital Library effort. Active Netlib was developed as a joint project with Morehouse College, the Joint Institute for Computational Science (JICS), and the Computational Fluid Dynamics Laboratory here at UT.

The progression of our repository efforts also continues with our work on NetBuild, which is a project to make it easier for authors and installers of application software to utilize standard computational software libraries. NetBuild intercepts calls to compilers and/or linkers, identifies which libraries are needed for an application, locates those libraries, downloads them, installs them, and links them into the executable. NetBuild thus eliminates the need for those libraries to be installed manually. NetBuild can also choose the "best" among several candidate libraries for a particular platform – for instance, using a BLAS that is optimized for the user's CPU instruction set extensions and cache sizes.

RECENT RESEARCH

The increase in computational intensive applications, coupled with an increase in computational power, has brokered a new era in the ability to handle data and metadata. Storing, moving, sharing, and processing this data puts

pressure on developers to find efficient ways to keep pace with such resource demands. RIB has been completely rewritten in Java over the past year to become more streamlined and flexible. By removing the built-in web server and database along with the scripts to manage both, the new incarnation of RIB decreases install time and leverages an object-oriented data model while still providing flexibility for catalog building and robust metadata interoperation. Many new features have also been added, such as the ability to navigate through all object components in a tree-like structure from the catalog view and new “join” features for creating flexible and browseable web-based matrices of classes. On the horizon for new features are improved database compatibility and tools for converting existing metadata into multiple, recognizable RIB formats.

There are ongoing discussions among the Netlib developers/administrators to overhaul the entire repository resource, from aesthetic and interface improvements to redefining the scope and type of the collection. While still very useful, the Netlib collection and the interface to it have remained largely unchanged over the past several years. One approach that has received considerable attention is to re-engage the mathematical community to create a more robust, dynamic repository with the ultimate goal of increasing contributions to the collection.

Our Active Netlib project has recently reached its goal of providing an inquiry-based learning environment for engineering students and educators, as well as practicing engineers.

Utilization of object oriented data models allows for interoperability between repositories	INTEROPERATION
New repositories use the BIDM by default	BIDM
Java Applet for customizing the BIDM or creating a new data model	DATA MODEL EDITOR
Java Applet for creating metadata objects conforming to the repository's data model	OBJECT EDITOR
Objects stored in open source RDBMS, which can generate XML representation of metadata objects	XML
Customizable HTML browse and search pages automatically generated	EXAMPLE USER VIEW 

Elements of a RIB Repository

With NetSolve servers running at both UT and Morehouse College, Active Netlib now provides client-server style access to resources such as mathematical software and engineering applications. Using multiple interfaces including Matlab, Java applets, and HTML forms, users may interact with the resources and receive feedback from the system on design decisions. Members of the scientific computing and engineering communities are invited to contribute additional resources to the collection.

NetBuild is currently being extended to support additional platforms, “include” files needed during source compilation, and the ability to utilize other library package formats and other repositories. NetBuild libraries are also now cryptographically signed, and the signatures verified as the libraries are downloaded in order to deter “Trojan horse” attacks.

Over the past 15 years, much of our success can be attributed to our staff.

However, our staff is just part of the formula. Equally important has been the wealth of talent provided by our students over the years. In addition, we have developed partnerships and collaborations with individuals and organizations around the world that play an integral part in our ability to stay at the forefront of high performance computing research. The working relationships that

we have established within the HPC community have been instrumental in our achievements. Our staff and students, our partners and collaborators, and the many commercial vendors with which we work have helped us build a strong foundation for fostering creative, original research.

Our full and part-time staff of 36 has a truly international flavor with over a dozen countries represented. Our ability to attract such experts from around the world is only one reason ICL remains a world leader in enabling technology. Most of our research staff hold advanced degrees and some began their ICL association as visiting researchers or students.

As an academic research group, we have an inherent responsibility to teach. Because we are part of the computer science (CS) department of a large university, we have access to both graduate and undergraduate students. With a CS program consisting of nearly 200 students, additional help with our projects is just a job posting away. These students represent a resource that is not readily available to many research groups, and we have been very proactive in securing internships and assistantships for those students who are motivated, hard working, and willing to learn. In addition to our large staff, we are proud to support 16 students, both graduate and undergraduate.

Since our group was founded, we routinely host numerous visitors from around the globe. Some of our visitors stay briefly to give seminars or presentations while many remain with us for as long as a year collaborating, teaching, and learning. Though many of our visitors are professors from various international universities, we also host researchers and administrators from many research institutions. In addition, it is not uncommon to have students (undergraduate as well as graduate) from various universities study with us for months on end, learning about our approaches and solutions to computing problems. In fact, many Ph.D. students from universities as far away as Japan have passed through our doors in an effort to broaden their understanding of linear algebra techniques and how we apply them to our research. The experience shared between our visitors and ourselves has been extremely beneficial to us, and we will continue providing opportunities for visits from our international colleagues in research. See page 20 for the many guests who have stopped by in the last year to exchange ideas and share their expertise with us. We have worked hard to create and maintain many collaborative relationships and are always eager to open doors to new opportunities for sharing research endeavors.

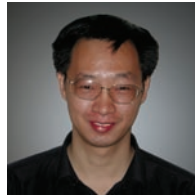
A testament to the experience and knowledge gained while working at ICL is perhaps best expressed by the multitude of students and staff who have continued their research efforts away from ICL. Many of our alumni are now applying their skills at companies such as Hewlett-Packard, Hitachi, IBM, Inktomi, Intel, Microsoft, Myricom, NEC, SGI, Sun Microsystems, and many others. A complete list of our alumni can be found on pages 20-21.



ICL STAFF AND STUDENTS



Sudesh Agrawal
Research Associate



Zizhong Chen
Graduate Research Assistant



Victor Eijkhout
Research Assistant Professor



Teresa Finchum
Administrative Services Assistant



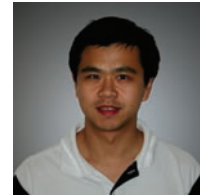
Bivek Agrawal
Graduate Research Assistant



Tom Cortese
Research Scientist - CE Onsite Lead



Brett Ellis
Sr. Computer Systems Specialist



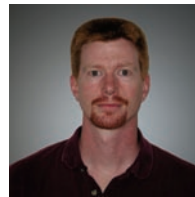
Xiaoquan Fu
Graduate Research Assistant



Thara Angskun
Graduate Research Assistant



David Cronk
Research Leader



Shawn Ericson
Research Associate



Erika Fuentes
Graduate Research Assistant



Nikhil Bhatia
Graduate Research Assistant



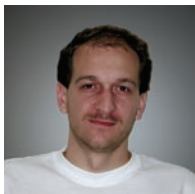
Jack Dongarra
University Distinguished Professor



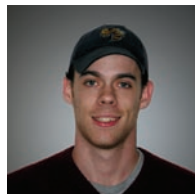
Graham Fagg
Research Associate Professor



Nathan Garner
Research Consultant



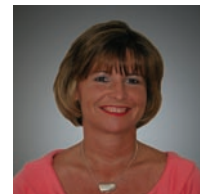
George Bosilca
Sr. Research Associate



Brian Drum
Consultant



Don Fike
Research Assistant



Alice Gregory
Administrative Support Assistant

ICL STAFF AND STUDENTS CONTINUED



Jan Jones
Publications Coordinator



Piotr Luszczyk
Sr. Research Associate



Phil Mucci
Research Consultant



Julien Langou
Sr. Research Associate



Eric Meek
Consultant



Shankar Narasimhaswami
Graduate Research Assistant



Jeff Larkin
Graduate Research Assistant



Shirley Moore
Associate Director



Paul Peltz
IT Administrator



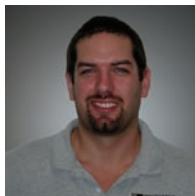
Tracy Lee
Accounting Specialist II



Keith Moore
Sr. Research Associate



Jelena Pjesivac-Grbovic
Graduate Research Assistant



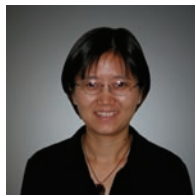
Kevin London
Research Assistant



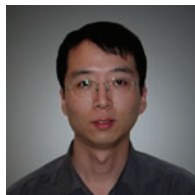
Terry Moore
Associate Director



Tracy Rafferty
Business Manager



Mei Ran
Graduate Research Assistant



Fengguang Song
Graduate Research Assistant



Scott Wells
Assistant Director



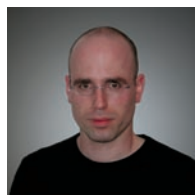
Haihang You
Research Associate



David Rogers
Graphic Designer



Dan Terpstra
Research Leader



Felix Wolf
Sr. Research Associate



Yuanlei Zhang
Graduate Research Assistant



Kiran Sagi
Research Associate



Joe Thomas
Research Associate



Jiayi Wu
Graduate Research Assistant



Keith Seymour
Sr. Research Associate



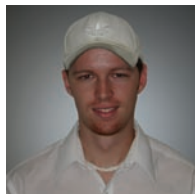
Stanimire Tomov
Sr. Research Associate



Qiu Xia
Consultant



Zhiao Shi
Graduate Research Assistant



Michael Walters
Undergraduate Student Assistant



Asim YarKhan
Sr. Research Associate

ICL QUICK STATS

FULL-TIME STAFF 29
PART-TIME STAFF 7
STUDENTS 16

RECENT VISITORS TO ICL

Panagiotis Adamidis
University of Stuttgart – Germany

Richard Barrett
The Arctic Region Supercomputing Center

David Bernholdt
ORNL

Alfredo Buttari
University of Rome – Italy

Andrew Canning
Lawrence Berkeley National Laboratory

Franck Cappello
INRIA - France

Henri Casanova
University of California San Diego

Dennis Crain
Microsoft

Luiz DeRose
Cray, Inc.

Zoran Dimitrijevic
Google

Thom Dunning
Joint Institute for Computational Science

Kyril Faenov
Microsoft

Dan Fay
Microsoft

Patrick Geoffray
Myricom

Sven Hammarling
The Numerical Algorithms Group LTD – UK

William Hargrove
ORNL

Forrest Hoffman
ORNL

Emmanuel Jeannot
LORIA INRIA-Lorraine – France

Alexey Lastovetky
University College Dublin, Ireland

Sabine Le Borne
Tennessee Tech University

Sunil Navale
Northrop Grumman, Inc.

Kenneth Roche
ORNL

Stephen Scott
ORNL

Brian Smith
Numerica 21, Inc.

Jeff Squyres
University of Indiana

Marvin Theimer
Microsoft

Srinidhi Varadarajan
Virginia Polytechnic Institute

Juan Vargas
Microsoft

Jeff Vetter
ORNL

Pat Worley
ORNL

Kamen Yotov
Cornell University

ICL ALUMNI

Carolyn Aebischer 1990-1993

Ed Anderson 1989-1991

Papa Arkhurst 2003

Dorian Arnold 1999-2001

Zhaojun Bai 1990-1992

Ashwin Balakrishnan 2001-2002

Richard Barrett 1992-1994

Alex Bassi 2000-2001

Micah Beck 2000-2001

Adam Beguelin 1991

Annamaria Benzoni 1991

Scott Betts 1997-1998

Noel Black 2002 - 2003

Susan Blackford 1989-2001

Fernando Bond 1999-2000

Randy Brown 1997-1999

Murray Browne 1998-1999

Cynthia Browne 2001, 2003

Antonin Bukovsky 1998 - 2003

Greg Bunch 1995

Henri Casanova 1995-1998

Sharon Chambers 1998-2000

Jaeyoung Choi 1994-1995

Eric Clarkson 1998

Andy Cleary 1995-1997

Jason Cox 1993-1997

Cricket Deane 1998-1999

Frederic Desprez 1994-1995

Jun Ding 2001 - 2003

Jin Ding 2003

Martin Do 1993-1994

Leon Dong 2000-2001

David Doolin 1997

Andrew Downey 1998 - 2003

Mary Drake 1989-1992

Julio Driggs 2002 - 2004

Zachary Eyler-Walker 1997-1998

Lisa Ezzell 2003 - 2004

Markus Fischer 1997-1998

ICL ALUMNI CONTINUED

Edgar Gabriel 2003 - 2004	Michael Kolatis 1993-1996	Tom Rothrock 1997-1998
Lynn Gangwer 2000-2001	Amanda Laake 2003 - 2004	Tom Rowan 1993-1997
Tracy Gangwer 1992 - 1993	DongWoo Lee 2000 - 2002	Evelyn Sams 1998-1999
Kelley Garner 1998	Todd Letsche 1993-1994	Farial Shahnaz 2001
Jonathan Gettler 1996	Sharon Lewis 1992-1995	Majed Sidani 1991-1992
Eric Greaser 1993	Xiang Li 2001	Shilpa Singhal 1996-1998
Stan Green 1992-1996	Weiran Li 2002	Thomas Spencer 1999-2001
Hunter Hagewood 2000-2001	Chaoyang Liu 2000	Erich Strohmaier 1995-2001
Christian Halloy 1996-1997	Matt Longley 1999	Martin Swany 1996-1999
Sven Hammarling 1996-1997	Richard Luczak 2000-2001	Daisuke Takahashi 2002
Hidehiko Hasegawa 1995-1996	Robert Manchek 1990-1996	Judi Talley 1993-1999
Satomi Hasegawa 1995-1996	Tushti Marwah 2004	Keita Teranishi 1998
Chris Hastings 1996	Paul McMahan 1994-2000	John Thurman 1998-1999
David Henderson 1999-2001	Jeremy Millar 1998-2002	Francoise Tisseur 1997
Greg Henry 1996	Michelle Miller 1999 - 2003	Bernard Tourancheau 1993-1994
Sid Hill 1996-1998	Cindy Mitchell 2001 - 2002	Lauren Vaca 2004
George Ho 1998-2000	Steven Moulton 1991-1993	Sathish Vadhiyar 1999 - 2003
Jeff Horner 1995-1999	Peter Newton 1994-1995	Robert van de Geijn 1990-1991
Yan Huang 2000-2001	Caroline Papadopoulos 1997-1998	Scott Venckus 1993-1995
Chris Hurt 2002	Leelinda Parker 2002	Reed Wade 1990-1996
Paul Jacobs 1992-1995	Antoine Petitot 1993-2001	R. Clint Whaley 1991-2001
Weizhong Ji 1999-2000	James S. Plank 1991 - 1992	Susan Wo 2000-2001
Weicheng Jiang 1992-1995	Roldan Pozo 1992-1994	Tinghua Xu 1998-2000
Song Jin 1997-1998	Tammy Race 1999-2001	Tao Yang 1999
Balajee Kannan 2001	Ganapathy Raman 1998-2000	Yong Zheng 2001
David Katz 2002	Kamesh Ramani 2003	Luke Zhou 2000-2001
Youngbae Kim 1992-1996	Yves Robert 1996-1997	Min Zhou 2004
MyungHo Kim 1998	Ken Roche 1999 - 2004	

One of our important resources is our computing hardware platforms. Remaining at the leading edge of research requires that we understand the nuances of hardware heterogeneity. To this end, we are required to have access to a variety of hardware resources. Our ability to develop and test our efforts on the best and latest equipment is one reason we are able to remain at the forefront of enabling technology research. Here at ICL, we maintain systems ranging from individual desktops to large, networked clusters. In addition, we have the resources necessary to parallelize many applications that previously ran only sequentially. Below is a summary of the many local computing resources used by ICL.



The following are the in-house systems that we use on a daily basis to test our work:

32 node Intel P4 cluster connected with Dolphin Networks	IBM Power 3s
Commodity-based Itanium clusters	SGI Octane
Compaq Alphas	64 node AMD Opteron cluster connected with Myrinet 2000

As an academic research group that is part of a large Computer Science department, we leverage additional resources including several server class machines and several HPC clusters. These clusters consist of multiple architectures including Itaniums, Itanium2s, Pentium IIIs, Pentium 4s, and AMD processors that comprise over 100 machines with various architectures. All of our clusters are arranged in the classic Beowulf configuration in which machines are connected by low latency, high-speed network switches.

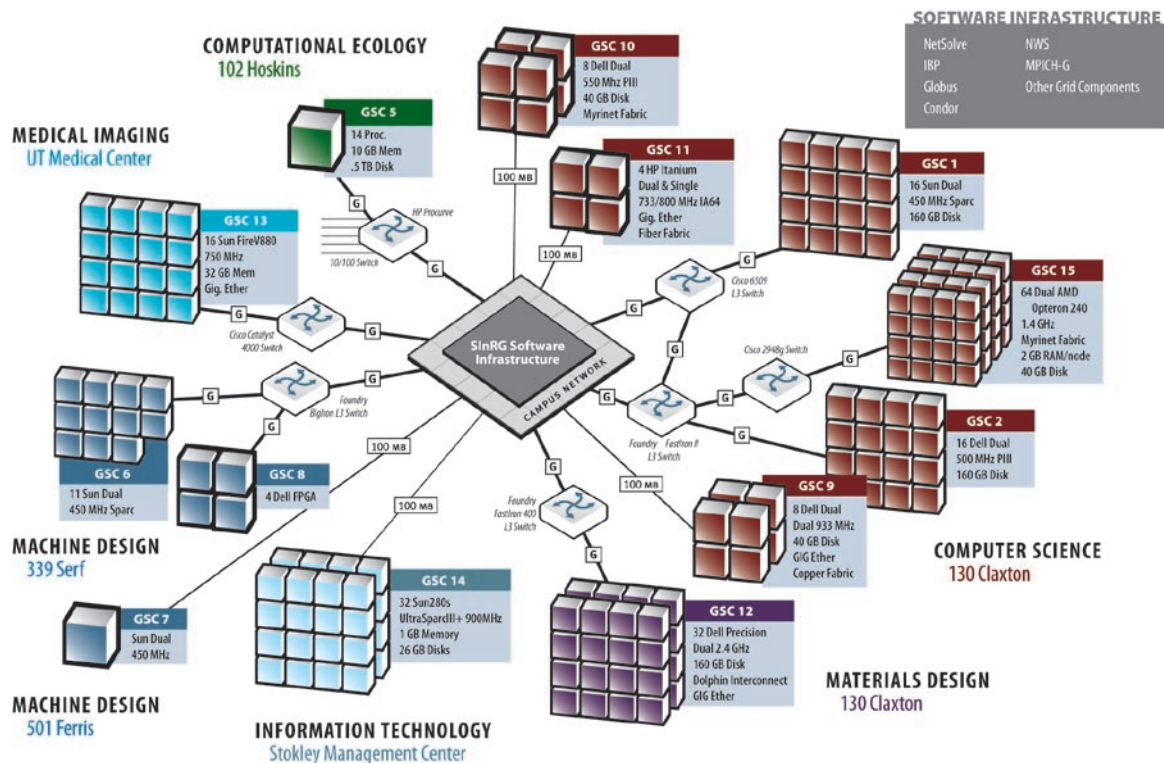
Our collaborative efforts allow us access to additional resources. We regularly retain remote access to many other HPC machines and architectures, some of which are regularly found in the Top500 list of the world's fastest supercomputers. The recent modernization of the DOE's Center for Computational Sciences, just 30 minutes away at the Oak Ridge National Laboratory (ORNL), will enable us to leverage our ORNL collaborations to take advantage of what will soon become the world's fastest scientific computing facility. Below are some of the systems that we currently utilize:

Our ability to develop and test our efforts on the best and latest equipment is one reason we are able to remain at the forefront of enabling technology research.

IBM SP, Power 3, 4 and 4+, and Cluster 1600	Cray T3E, SV1, SV1ex, and X1
SGI Origin 2000, 3000, 3800, 3900	Compaq SC40 and 45
Several large Linux Clusters	

All of ICLs Grid computing research is supported by the Scalable Intracampus Research Grid (SinRG), an NSF funded research infrastructure established by the UT Computer Science department under ICL's leadership. This infrastructure provides hardware computing resources within the boundaries of the Knoxville campus for interdisciplinary research collaborations that are indicative of the national and international technology Grid allowing students, faculty, and other researchers at UTK, including ICL, to address important challenges of grid-based computing using the advantages of local communication and central administration.

Current SinRG deployment on UTK campus



In addition, we possess an Access Grid (AG) node, which consists of various interfaces and environments on the Grid that support distributed meetings, lectures, tutorials, and other collaborative efforts. The AG comprises multiple video cameras, speakers, projectors, and PCs to form a seamless resource for conducting timely, online collaborative activities. The AG has become an invaluable tool and resource for collaborating with the many organizations and institutions with which we conduct joint research.

ICL continues to explore and foster collaborations all over the globe. It has been our ability to develop relationships with institutions and organizations within the high performance computing (HPC) community that has allowed our sustained growth over the years. The HPC community consists of academic institutions, research centers, branches of the federal government, and various other public and private organizations, both domestic and international. We also routinely develop relationships with researchers whose primary focus is other scientific disciplines, such as biology, chemistry, and physics, which makes our collaborations truly multidisciplinary. We continue to stress the importance of these solid partnerships and we are always eager to establish new ones. Our mutually beneficial collaborative initiatives have strengthened our research efforts by allowing us to share both material and intellectual resources. The following tables highlight many of our domestic partners and collaborators. As our list of government and academic partners continues to grow, we hope to also develop additional partnerships with commercial software vendors. Some of the vendors who have incorporated our work in their applications include Intel, Inc. who now develops the KAP/Pro toolset and the Vampir performance visualization and analysis tool, The Mathworks, Inc. who develops Matlab, and Etnus, Inc., developer of the TotalView debugger.

The world map on page 25 shows the location of many of the domestic and international partners and collaborators in research with whom we continue to work.

DOMESTIC COLLABORATORS

ANL ARGONNE NATIONAL LABORATORY

CACR CALIFORNIA INSTITUTE OF TECHNOLOGY CENTER FOR ADVANCED COMPUTING RESEARCH

CRPC THE CENTER FOR RESEARCH ON PARALLEL COMPUTATION

DARPA DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

DoD THE UNITED STATES DEPARTMENT OF DEFENSE

DoD HPCMP THE DOD HIGH PERFORMANCE COMPUTING MODERNIZATION PROGRAM

DOE THE UNITED STATES DEPARTMENT OF ENERGY

DOE2000

Emory University

IBM INTERNATIONAL BUSINESS MACHINES

Intel Corporation

Internet2

ISI INFORMATION SCIENCES INSTITUTE

I2-DSI THE INTERNET2 DISTRIBUTED STORAGE INFRASTRUCTURE

JICS ORNL/UT JOINT INSTITUTE FOR COMPUTATIONAL SCIENCE

LANL LOS ALAMOS NATIONAL LABORATORY

LLNL LAWRENCE LIVERMORE NATIONAL LABORATORY

Microsoft Research

Morehouse College

MRA METACENTER REGIONAL ALLIANCE

NASA NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NCSA THE NATIONAL COMPUTATIONAL SCIENCE ALLIANCE

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

NPACI THE NATIONAL PARTNERSHIP FOR ADVANCED COMPUTATIONAL INFRASTRUCTURE

NSF THE NATIONAL SCIENCE FOUNDATION

ORNL CSMD THE COMPUTER SCIENCE AND MATHEMATICS DIVISION OF OAK RIDGE NATIONAL LABORATORY

Rice University

SDSC SAN DIEGO SUPERCOMPUTING CENTER

SGI SILICON GRAPHICS INCORPORATED

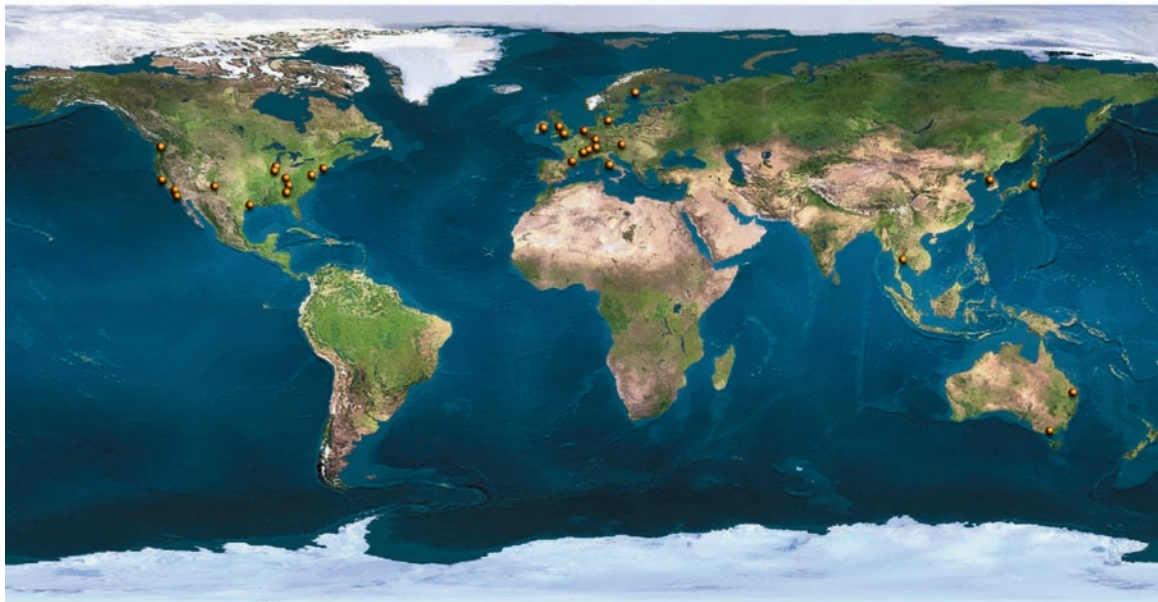
Sun Microsystems

University of California, Berkeley

University of California, San Diego

University of Kentucky

UTK-CS THE COMPUTER SCIENCE DEPARTMENT OF THE UNIVERSITY OF TENNESSEE



Map of domestic and international collaborators

INTERNATIONAL COLLABORATORS

- Danish Computing Center for Research and Education** LYNGBY, DENMARK
Dept of Mathematical and Computing Sciences - Tokyo Institute of Technology JAPAN
Dept of Mathematics - University of Manchester ENGLAND
CERFACS - European Centre for Research and Advanced Training in Scientific Computing TOULOUSE, FRANCE
Fakultät für Mathematik und Informatik - Universität Mannheim MANNHEIM, GERMANY
Forschungszentrum Jülich Central Institute for Applied Mathematics JÜLICH, GERMANY
Institut für Wissenschaftliches Rechnen - ETH Zentrum ZÜRICH, SWITZERLAND
Istituto per le Applicazioni del Calcolo - "Mauro icone" del C.N.R. ROME, ITALY
Intelligent Systems Design Laboratory - Doshisha University KYOTO, JAPAN
Kasetsart University BANGKOK, THAILAND
Laboratoire de L'Informatique du Parallelisme, École Normal Superieure de Lyon LYON, FRANCE
Mathematical Insitute - Utrecht University NETHERLANDS
Monash University MELBOURNE, AUSTRALIA
Numerical Algorithms Group Ltd OXFORD, ENGLAND
PHASE - Parallel and HPC Application Software Exchange TSUKUBA, JAPAN
Queenland University of Technology BRISBANE, AUSTRALIA
RESAM - Laboratoire Réseaux Haut Débits et Support d'Applicatoins Multimedia Jeune Equipe de l'Université Claude Bernard de Lyon LYON, FRANCE
Rutherford Appleton Laboratory OXFORD, ENGLAND
Scole Polytechnique Federale de Lausanne LAUSANNE, SWITZERLAND
Soongsil University SEOUL, SOUTH KOREA
Technische Universitaet Wien VIENNA, AUSTRIA
Universita' di Roma "Tor Vergata" ITALY
University College Dublin IRELAND
University of Umeå UMEÅ, SWEDEN

ICL QUICK STATS

INTERNATIONAL COLLABORATORS 24
DOMESTIC RESEARCH PARTNERS 34



CITR

CENTER FOR INFORMATION
TECHNOLOGY RESEARCH

After four years of operation, the Center for Information Technology Research (CITR), directed by Dr. Jack Dongarra and co-located with ICL, has fulfilled all the expectations that the University of Tennessee (UT) had when it established the Research Center program. The program was created as part of a strategic effort to become one of America's top 25 public research universities. It promised to dramatically enhance the flow of research funding into the university, thereby helping to impact the state's economy, create new jobs, and spawn new companies. Of the nine research centers of excellence — five in Knoxville and four at the Health Science Center in Memphis — CITR ranked second, bringing in \$36.1 million in new research funding, just behind the Center for Genomics and Bioinformatics. Since UT's investment over that period was \$2.7 million, CITR's rate of return on investment has been 13 to 1.

BACKGROUND

From its inception in the spring of 2001, CITR has been focused on increasing the growth and development of leading edge Information Technology Research (ITR) at the University of Tennessee. ITR is a broad, multi-disciplinary area that investigates the ways in which fundamental innovations in Information Technology affect, and are affected, by the research process.

CITR's mission is to build up a thriving, well-funded community in basic and applied ITR at the University of Tennessee in order to help the university capitalize on the rich supply of research opportunities that now exist in this area. CITR's primary strategy in carrying out this mission has been to invest in a diverse group of ITR laboratories, each one led by an established researcher or an emerging leader in some significant area of ITR. Although CITR has also made small investments in collateral activities — challenge grants for new IT researchers, contributions to start up packages for stellar new faculty, enhanced graduate stipends in ITR-related fields — it has concentrated on the ITR laboratories, and this concentration has produced the majority of its successes.



CITR LABORATORIES

CITR investments in ITR Laboratories target researchers with the potential for generating well-funded research, but also aim to diversify the range of research opportunities and funding sources that UT can address. The first CITR laboratory, and the model for others, is the ICL. In addition to ICL, two more CITR Laboratories have been formed: The Logistical Computing and Internetworking (LoCI) Lab, co-directed by Professors Micah Beck and Jim Plank from the Computer Science Department; and The Institute for Environmental Modeling (TIEM) led by Professor Lou Gross from the Departments of Ecology and Evolutionary Biology and Mathematics. Along with the strong growth in funding and the many other accomplishments the CITR labs have produced, in the past two years both ICL and TIEM have received large awards from the National Science Foundation's prestigious and highly competitive Information Technology Research Program.

UT'S RESEARCH CENTERS OF EXCELLENCE

The full list of UT's Research Centers of Excellence (and their respective directors), includes the following:

CENTERS BASED IN KNOXVILLE

Center for Information Technology Research

DR. JACK DONGARRA

Advanced Materials Center

DR. WARD PLUMMER

Environmental Biotechnology Center

DR. GARY SAYLER

Food Safety Center

DR. STEPHEN P. OLIVER AND DR. ANN DRAUGHON

Structural Biology Center

DR. ENGIN SERPERSU

CENTERS BASED IN MEMPHIS

Connective Tissues Diseases Center

DR. ANDREW H. KANG

Genomics and Bioinformatics Center

DR. DAN GOLDDOWITZ

Neurobiology and Imaging of Brain Disease Center

DR. WILLIAM A. PULSINELLI

Vascular Biology Center

DR. LISA JENNINGS

2004

Agarwal, P., Alexander, R., Apra, E., Balay, S., Bland, A., Colgan, J., D'Azevedo, E., Dongarra, J., Dunigan, T., Fahey, M., Fahey, R., Geist, A., Gordon, M., Harrison, R., Kaushik, D., Krishnakumar, M., Luszczek, P., Mezzacapa, T., Nichols, J., Nieplocha, J., Olikier, L., Packwood, T., Pindzola, M., Schulthess, T., Vetter, J., White, J., Windus, T., Worley, P., Zacharia, T. "Cray X1 Evaluation Status Report," Oak Ridge National Laboratory Report, ORNL/TM-2004/13, January, 2004.

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Fagg, G., Gabriel, E., Bosilca, G., Angskun, T., Chen, Z., Pjesivac-Grbovic, J., London, K., Dongarra, J. "Extending the MPI Specification for Process Fault Tolerance on High Performance Computing Systems," Proceedings of ISC2004 (to appear), Heidelberg, Germany, June 23, 2004.

Fagg, G., Gabriel, E., Chen, Z., Angskun, T., Bosilca, G., Pjesivac-Grbovic, J., Dongarra, J. "Process Fault-Tolerance: Semantics, Design and Applications for High Performance Computing," International Journal for High Performance Applications and Supercomputing (to appear), April, 2004.

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