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13. ABSTRACT (Maximum 200 words)

High Performance Computing (HPC) is an enabling technology for a large class of Army needs including weapon system design, simulation and modeling, intelligence, automation, advanced manufacturing, and training. Recognizing this, in 1989 Army established the Army HPC Research Center. The Center consists of four integrated activities: interdisciplinary research into various aspects of HPC including novel solution techniques, advanced algorithms, applications, and graphics and visualization (GV); evaluation of advanced computing systems and implementation of an advanced HPC environment; infrastructure support and technology transfer to Army and other DoD activities; and, an aggressive outreach program through participation of Historically Black Colleges and Universities (HBCU) and Minority Institutions. The prime contractor for the Center is the University of Minnesota; its HBCU partners are Clark Atlanta, Florida A&M, Howard, and Jackson State Universities; and its industrial partner, the Minnesota Supercomputer Center, Inc. (MSCI), maintains and operates the supercomputing resources of the Army HPC Research Center.

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RESEARCH SUMMARY

Abstract

High Performance Computing (HPC) is an enabling technology for a large class of Army needs including weapon system design, simulation and modeling, intelligence, automation, advanced manufacturing, and training. Recognizing this, in 1989 Army established the Army HPC Research Center. The Center consists of four integrated activities: interdisciplinary research into various aspects of HPC including novel solution techniques, advanced algorithms, applications, and graphics and visualization (GV); evaluation of advanced computing systems and implementation of an advanced HPC environment; infrastructure support and technology transfer to Army and other DoD activities; and, an aggressive outreach program through participation of Historically Black Colleges and Universities (HBCU) and Minority Institutions. The prime contractor for the Center is the University of Minnesota; its HBCU partners are Clark Atlanta, Florida A&M, Howard, and Jackson State Universities; and its industrial partner, the Minnesota Supercomputer Center, Inc. (MSCI), maintains and operates the supercomputing resources of the Army HPC Research Center.

Research Activities

A number of Center interdisciplinary research teams worked on HPC strategies using advanced computing systems, and applied these powerful strategies to Army problems. The Simulation and Modeling Team focused on techniques to provide solutions to complex, 3D problems. Finite element computation of compressible and incompressible flows involving complex geometries with moving boundaries and interfaces is one of the major Center activities. In this area, ARL and Center researchers are collaborating on the regenerative liquid propellant gun (RLPG) and on missile aerodynamics. In a collaborative effort with Natick RDEC, the Center is simulating the deployment and gliding of large ram-air parachutes.

The Advanced Manufacturing Team focused on HPC techniques and software for advanced material design and manufacturing processes. The advanced material design efforts emphasize simulation of resin transfer molding and include collaborations with ARL and Center for Composite Materials (CCM) at University of Delaware. The efforts in manufacturing processes emphasize computer aided manufacturing, including process planning for on-demand manufacture, and algorithms and software for vision, robotics, and adaptive control.

The Environmental Sciences Team is working with the CEWES in application of advanced HPC techniques to groundwater modeling and environmental fluid mechanics. These activities include developing new models to predict the dispersion, absorption, capillary pressure, and dissolution of contaminants in groundwater, as well as developing new computational hydrodynamics tools based on the Navier-Stokes equations and their shallow-water approximations.

The Information Technology and Algorithms and Software Technology Teams are focusing on tools which facilitate efficient and easy implementation of many applications on various advanced HPC architectures. These tools include parallel scalable algorithms and libraries; database support for manufacturing and simulation; and virtual interactive distributed simulation. These teams also focus on visualization of large data sets resulting from simulations based on structured and unstructured computational grids. In a joint effort with TARDEC, the Center researchers are also working on numerical methods and software for real-time simulation of multibody systems and interactions between rigid-body systems and deformable systems.

Advanced HPC Environments

As a result of an aggressive acquisition and systems integration program as well as being able to capitalize on the computing environment extant at the MSCI, Army Center researchers have access to a feature-rich, robust, heterogeneous computing environment that is a model for excellence in HPC. The hardware provided by the Army includes a Thinking Machines CM-5 with 896 processing nodes and an advanced GV lab, whereas the MSCI computational resources include a Cray T3D with 128 processing nodes, a Cray Y-MP C90 with 9 processors, and a Cray-2 with 4 processors. This integrated environment provides researchers with the latest in computing technology, high-speed networking, and user-friendly system and graphics utilities.

The Army Center researchers have always been at the forefront of effective and relevant utilization of advanced HPC systems. Soon after the CM-5 supercomputers became available nationwide, the Center researchers were among the first to carry out application computations on this platform. The Center researchers were also among the first who carried out application computations on the Cray T3D. At Supercomputing '92, the Center used heterogeneous computing in simulating thermal flows in the Earth's mantle. The application executed on four different HPC platforms: a CM-5, a Cray-2, a CM-200, and an SGI workstation. This demonstration was judged the "Best of the Best" in Supercomputing '92 Heterogeneous Challenge Competition. In another heterogeneous computing application, recently the Center researchers simulated the flow inside a RLPG by using the Cray C90 at MSCI for the direct solution of the coupled equations, while using the Center's CM-5 for the rest of the computations. The exchange of data every time step was accomplished over a HIPPI channel.

The GV Laboratory at the Center is a unique facility specifically to support the demanding requirements of visualization of gigabyte-size data sets. With the software written mostly at the Center, the researchers were able to visualize the 3D flow simulation data generated by using structured grids as well as unstructured grids on complicated geometries.

Software Development

The Center supported efforts to develop systems software, mathematical subroutine libraries, GV tools, and applications software. These were made available to the broader Army and HPC community through on-line libraries and one-on-one research collaborations. A good example of the system software developed at the Center is Distributed Job Manager which provides interactive and optimal use of parallel computer resources.

In the category of GV software, Brick-of-Bytes (BOB) has been very widely disseminated to government, academe and industry. For example, BOB is extensively used by researchers in their modeling of composite materials at the CCM. BOB provides for interactive volume rendering, and efficiently visualizes very large 3D data sets.

DASPK, a mathematical subroutine library of iterative algorithms for solving differential algebraic equation systems, and its data-parallel and message-passing-parallel versions found widespread acceptance at many research sites across the country and is used extensively at TARDEC.

Application software developed at the Center have also proven to be very useful to the Army. For example, about the software developed for the flow simulation inside a RLPG, an Army official commented that this software "...provided crucial analysis in a short time-frame which was instrumental in the rapid recovery of our weapon to the firing line.".

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Technology Transfer, Training and Collaboration

The Center has a major commitment to technology transfer, training and collaboration. As an innovative computational testbed, it is the focus of several technology transfer projects designed to move university research directly into Army labs and research centers. Several infrastructure support experts placed at both the Center and the Army labs played a vital role in the day-to-day operation of the Center and were an important link to the research program, serving as a bridge between the university and Army researchers. Eaxmples of technology transfer and collaborative projects with the Army sites are:

- Real-time simulation of large-scale multibody systems (TARDEC)
- Design of liquid propellant guns (ARL)
- Groundwater modeling (CEWES)
- Parafoil aerodynamics (Natick RDEC)
- Resin transfer molding (ARL)

The Center researchers have also been involved in industrial collaborations in areas such as hardware and software development, materials processing, environmental fluid mechanics, and flow simulation of high-speed transportation vehicles.

International collaborations were also encouraged. Examples include collaborations with the Chuo University in Japan; Observatoire de la Cote d'Azur in France; and Ecole Centrale de Lyon in France.

Education, Training and Outreach

Many Ph. D., M. S., and undergraduate students were involved in the Center research projects. Approximately 20-25 graduate students and 10-15 postdoctoral fellows were funded each year by the Center. Additional graduate students and postdoctoral fellows were funded by other federal, state and industrial research grants leveraged by the resources and activities at the Center. For example, three of the postdoctoral fellows originally funded by the Center were also awarded Postdoctoral Associateships in Computational Science and Engineering by the National Science Foundation. Graduate students were encouraged to spend time at the Army labs, working on projects supervised jointly by the Army and Center researchers. A Center graduate student who spent several months at the ARL working on numerical simulation of liquid propellant guns later accepted a postdoctoral appointment there.

Since the Summer of 1991, the Center has organized an annual six-week summer institute for training of promising undergraduate students. Each summer, 15-20 students from the United States and Puerto Rico attended this intensive training in HPC, with emphasis on numerical methods, parallel computing, and GV. The program also encouraged these students, especially women and minorities, to pursue graduate studies or careers in HPC. The Center faculty, postdoctoral fellows, and graduate students served as lecturers and project mentors for the students. The Army researchers were also invited to give lectures, providing information on the research activities at the Army labs and potential internship and career opportunities. The 1994 Summer Institute had 18 students from 13 institutions including Clark Atlanta, Florida A&M, Howard, and Jackson State Universities.

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94-042 J. Feng, H. Hu, and D. Joseph, Direct simulation of initial value problems for the motion of solid bodies in a Newtonian fluid: Part I. Sedimentation

94-043 G. Wren, S. Ray, S. Aliabadi, and T. Tezduyar, Space-time finite element computation of compressible flows between moving components

94-044 Z. Shao, Inertial manifolds for partly dissipative reaction diffusion systems in higher space dimensions

94-045 M. Lin, J. Hsieh, D. Du, J. Thomas, and J. MacDonald, Distributed network computing over local ATM networks

94-046 J. Bourgeois and G. Smith, A fully three-dimensional simulation of a ground-penetrating radar: FDTD theory compared with experiment

94-047 S. Mittal and T. Tezduyar, Parallel finite element simulation of 3D incompressible flows–Fluid-structure interactions

94-048 Q. Xiao, A. Salinger, Y. Zhou, and J. Derby, Massively parallel finite element analysis of coupled, incompressible flows: A benchmark computation of baroclinic annulus waves

94-049 S. Aliabadi and T. Tezduyar, Parallel fluid dynamics computations in aerospace applications

94-050 Y. Zhou and J. Derby, The cathode design problem in electrochemical machining

94-051 P. McQueen, D. Hess, and J. Serene, Pseudogap formation in the symmetric Anderson lattice model

94-052 C. Smith, S. Brandt, and N. Papanikolopoulos, Eye-in-hand robotic tasks in uncalibrated environments

94-053 C. Smith, S. Brandt, C. Richards, and N. Papanikolopoulos, Visual tracking for intelligent vehicle-highway systems

94-054   V. Kalro and T. Tezduyar, Parallel finite element computation of 3D incompressible flows, *Proceedings of the International Workshop on Solution Techniques for Large-Scale CFD Problems*, Sept. 26-28, pp 103-125

94-055   K. Kashiyama, H. Ito, M. Behr, and T. Tezduyar, Three-step explicit finite element computation of shallow water flows on a massively parallel computer

94-056   Q. Xiao and J. Derby, Three-dimensional melt flows in Czochralski oxide growth: High-resolution, massively parallel, finite element computations

94-057   A. Yeckel, A. Salinger, and J. Derby, Theoretical analysis and design considerations for float-zone refinement of electronic grade silicon sheets

94-058   M. Behr, D. Hastreiter, S. Mittal, and T. Tezduyar, Incompressible flow past a circular cylinder: Dependence of the computed flow field on the location of the lateral boundaries

94-059   C. Smith and N. Papanikolopoulos, Visually-guided, automatic grasping of static objects

94-060   J. Douglas, Jr., F. Pereira, and L.-M. Yeh, A parallelizable characteristic scheme for two phase flow I: Single porosity models

94-061   P. van Keken, Notes on a data parallel implementation of a multigrid method to solve Poisson's equation in 2D

94-062   S. Kuppurao, J. Derby, and S. Brandon, Modeling heat transfer and segregation during the vertical Bridgman growth of cadmium zinc telluride

94-063   G. Karypis and V. Kumar, A high performance sparse Cholesky factorization algorithm for scalable parallel computers

94-064   D. Challou, G. Karypis, M. Gini, and V. Kumar, Methods for predicting the performance of randomized parallel search: An application in robot motion planning

94-065   V. Voller, S. Peng, and Y. Chen, Numerical approaches for modeling filling in polymer molding processes

94-066   D. Hamnes and A. Tripathi, A comparative study of adaptive risk vs. adaptive aggressiveness control in parallel and distributed simulation

PARTICIPATION SUMMARY

NAME	POSITION	DEGREES AWARDED
Alizaheh, Farid	Research Assistant	Ph.D., Computer & Information Sciences
Almlöf, Jan	Faculty Researcher	
Anda, Andrew	HPC Graduate Fellow	Ph.D., Computer & Information Sciences
Aris, Rutherford	Faculty Researcher	
Averick, Brett	Research Associate	
Aw, Jian-Huei	Research Assistant	
Babin, Anatoli.	Visiting Fellow	
Bae, H. O.	Research Assistant	
Bassett, Gene	HPC Graduate Fellow	Ph.D., Astronomy
Behr, Marek	Research Assistant	Ph.D., Aerospace Engineering
Benjamin, Dean	HPC Graduate Fellow	Ph.D., Chemical Engineering
Berg, Brian	HPC Graduate Fellow	Ph.D., Aerospace Engineering
Bergner, Peter	Research Assistant	M.S., Electrical Engineering
Boley, Daniel	Faculty Researcher	
Bondarevsky, Vadim	HPC Graduate Fellow	M.S., Mathematics
Cai, Dongming	Research Assistant	Ph.D., Biomedical Engineering
Cai, Xiao-Chuan	Visiting Fellow	
Candler, Graham	Faculty Researcher	
Carmeli, Tidhar	Research Assistant	
Carney, Sandra	HPC Graduate Fellow	M.S., Computer & Information Sciences
Carter, Richard	Research Associate	
Challou, Dan	HPC Graduate Fellow	Ph.D., Computer & Information Sciences
Chambers, Candee Cae	Research Associate	
Chandrasekharan, Sridhar	Research Assistant	
Chang, Whie	Research Associate	
Chatfield, David	HPC Graduate Fellow	Ph.D., Chemistry
Claypool, Mark	Research Assistant	M.S., Computer & Information Sciences
Chen, Yih-Farn	Research Assistant	
Chen, Zhangxin	Research Associate	
Chronopoulos, Anthony	Faculty Researcher	
Cicarelli, Paolo	Postdoctoral Fellow	
Cockburn, Bernardo	Faculty Researcher	
Coyle, Mark	Research Assistant	
Dai, Wenlong	Research Assoicate	
Dahl, Peter	HPC Graduate Fellow	Ph.D., Electrical Engineering
Davis, H. Ted	Faculty Researcher	
Day, Paul	HPC Graduate Fellow	Ph.D., Chemistry
Derby, Jeffrey	Faculty Researcher	
Donath, Max	Faculty Researcher	
Douglas, Jr., Jim	Faculty Researcher	
Droegemeier, Kelvin	Visiting Fellow	
Du, David	Faculty Researcher	
Duh, Jenyue	Research Assistant	

NAME	POSITION	DEGREES AWARDED
Eaton, Brian	Research Assistant	
Edgar, B. Kevin	Research Associate	
Eichler West, Rogene	HPC Graduate Fellow	
Ellingson, James	HPC Graduate Fellow	
Emeagwali. Phillip	Research Fellow	
Eyre, David	Research Associate	
Felix, Paul	Research Assistant	M.S., Mechanical Engineering
Ferng, William	Research Associate	
Fosdick, Roger	Faculty Researcher	
Gackstetter, Gary	Research Assistant	Ph.D., Epidemiology
Gill, Tepper	Faculty Researcher	
Gini, Maria	Faculty Researcher	
Glick, John	HPC Graduate Fellow	Ph.D., Computer & Information Sciences
Grama, Ananth	Research Assistant	
Grieger, John	Postdoctoral Fellow	
Gupta, Anshul	Research Assistant	
Hagen, Aaron	Research Assistant	
Hari, Vjeran	Visiting Fellow	
Harris, Williams	Faculty Researcher	
Hensley, Jeffrey	Research Assoicate	
Hesla, Todd	HPC Graduate Fellow	
Hensley, Jeffrey	Research Assistant	Ph.D., Mathematics
Hou, S.	Research Assistant	
Hunt, Fern	Faculty Researcher	
James, Richard	Faculty Researcher	
Janardan, Ravi	Faculty Researcher	
Jay, Laurant	Visiting Fellow	
Johnson, Andrew	HPC Graduate Fellow	Ph.D., Aerospace Engineering
Jolly, Michael	Faculty Researcher	
Joseph, Daniel	Faculty Researcher	
Kaiho, Masayuki	Visiting Fellow	
Kawahara, Mutsuto	Visiting Fellow	
Kalro, Vinay	Research Assistant	
Karypis, George	Research Assistant	
Kashiyama, Kazuo	Visiting Fellow	
Kimball, Anthony	Research Fellow	
Kinderlehrer, David	Faculty Researcher	
Kumar, Vipin	Faculty Researcher	
Koohialiabadi, Shahrouz	Research Assistant	Ph.D., Aerospace Engineering
Kroll, Daniel	Visiting Fellow	
Kwak, Minkyu	Research Assistant	Ph.D., Mathematics
Leszczyn´ski, Jerzy	Faculty Researcher	
Li, Zhiyuan	Faculty Researcher	
Lilja, David	Faculty Researcher	
Lin, Mengou	Research Assistant	Ph.D., Computer & Information Sciences
Liou, James	Research Assistant	Ph.D., Mechanics
Litke, Matthew	Undergraduate Research Assistant	
Lou, Gang	Research Associate	
Lowengrub, John	Faculty Researcher	

NAME	POSITION	DEGREES AWARDED
Lucier, Bradley	Faculty Researcher	
Luskin, Mitchell	Faculty Researcher	
Maier, Robert	Research Associate	
Malevsky, Andrei	Research Associate	
Maly, Timothy	Research Assistant	M.S., Mathematics and Computer & Information Sciences
Mallet-Paret, John	Visiting Fellow	
Marion, Martine	Visiting Fellow	
Martin Aguirre, Maria	Research Assistant	
Mejia, John	HPC Graduate Fellow	Ph.D., Electrical Engineering
Melissas, Vasilios	Research Assistant	Ph.D., Chemistry
Mikula, Tim	HPC Graduate Fellow	Ph.D., Computer & Information Sciences
Misra, Debasmita	Postdoctoral Fellow	
Mittal, Sanjay	Research Assistant	M.S., Aerospace Engineering and Ph.D. Aerospace Engineering
Mohammadi, Bijan	Research Associate	
Mohan, Ram	Research Assistant	
Moore, Peter	Visiting Fellow	
Moré, Jorge	Faculty Researcher	
Necoechea, William	HPC Graduate Fellow	
Niccum, Thomas	HPC Graduate Fellow	M.S., Computer & Information Sciences
Nieber, John	Faculty Researcher	
Noble, Denis	Faculty Researcher	
Nurkkala, Thomas	Research Assistant	M.S., Computer & Information Sciences
Norman, David	Research Assistant	
Ofelt, David	Jr. Application Programmer	
O'Keefe, Matthew	Faculty Researcher	
Olejnicczak, Debra	Research Assistant	
Olsen, Robert	Research Associate	
Olwell, David	Visiting Fellow	
Pan, Houyao	Research Assistant	
Park, Haesun	Faculty Researcher	
Park, Kihong	Postdoctoral Fellow	
Parr, Terence	Research Assistant	Ph.D., Electrical Engineering
Peng, S. P.	Research Assistant	
Petzold, Linda	Faculty Researcher	
Phillips, Andrew	Visiting Fellow	
Pliss, Victor	Visiting Fellow	
Poliac, Marius	Research Associate	
Pong, Ting-Chuen	Faculty Researcher	
Porter, David	Research Fellow	
Raphael, Louise	Faculty Researcher	
Randall, Paul	Research Assistant	
Randall, Rick	Research Assistant	Ph.D., Chemical Physics
Raugel G.	Visiting Fellow	
Ravada, Sivakumar	Research Assistant	
Ray, Stephen	HPC Graduate Fellow	Ph.D., Aerospace Engineering

NAME	POSITION	DEGREES AWARDED
Retzel, Ernest	Faculty Researcher	
Riedl, John	Faculty Researcher	
Riley, Donald	Faculty Researcher	
Riordan, James	HPC Graduate Fellow	
Rogers, Kent	Research Assistant	
Roh, J.	Research Assistant	
Rosen, J. Ben	Faculty Researcher	
Rustad, James	HPC Graduate Fellow	Ph.D., Geology & Geophysics
Saad, Youcef	Faculty Researcher	
Sameh, Ahmed	Faculty Researcher	
Salinger, Andrew	HPC Graduate Fellow	Ph.D., Chemical Engineering
Samelson, Sandy	Research Associate	
Sargent, Andrew	Research Associate	
Sarin, Vivek	Research Assistant	M.S., Computer & Information Sciences
Scheaffer, Charles	Research Assistant	M.S., Computer & Information Sciences
Schmidt, Lanny	Faculty Researcher	
Scriven, L. E.	Faculty Researcher	
Sell, George	Faculty Researcher	
Sha, Desong	Research Fellow	
Shao, Zhoude	Research Assistant	Ph.D., Mathematics
Shekhar, Shashi	Faculty Researcher	
Shih, R. J.	Research Associate	
Shoop, Elizabeth	HPC Graduate Fellow	M.S., Computer & Information Sciences
Smith, Cecil	Research Assistant	
Smith, Christopher	Research Assistant	
Srivastava, Jaideep	Faculty Researcher	
Stelson, Kim	Faculty Researcher	
Stiegner, J.	Research Assistant	
Su, Dongli	Research Assistant	
Sullivan, Richard	Faculty Researcher	
Swaminthan, C. R.	Research Assistant	Ph.D., Mechanical Engineering
Tamma, Kumar	Faculty Researcher	
Tawa, Gregory	Research Associate	
Tezduyar, Tayfun	Faculty Researcher	
Thigpen, Lewis	Faculty Researcher	
Titi, Edriss	Visiting Fellow	
Triandaf, Ioana	HPC Graduate Fellow	Ph.D., Mathematics
Truhlar, Donald	Faculty Researcher	
Valli, Alberto	Visiting Fellow	
van Keken Peter	Visiting Fellow	
Varghese, Anthony	Research Assistant	Ph.D., Biomedical Engineering
Varghese, Thomas	Research Fellow	
Vetter, Ronald	Research Assistant	Ph.D., Computer & Information Sciences
Vincent, Alain	Visiting Fellow	
Vlachos, Dionisios, G.	Research Associate	
Voller, Vaughan	Faculty Researcher	
Waters, Christopher	Undergraduate Research Assistant	
Weinberger, Hans	Faculty Researcher	

NAME	POSITION	DEGREES AWARDED
Wijesekera, Duminda	Visiting Fellow	
Wilcox, George	Faculty Researcher	
Williams, Daniel	Faculty Researcher	
Williams, Kenneth	Research Assistant	Ph.D., Computer & Information Sciences
Winslow, Raimond	Faculty Researcher	
Woodward, Paul	Faculty Researcher	
Wright, Michael	Research Assistant	M.S., Aerospace Engineering
Wu, Kesheng	Research Assistant	
Xiao, Qiang	Research Fellow	
Xue, Guo-Liang	Research Associate	
Yan, Yin	Research Associate	Ph.D., Mathematics
Yang, Guo-Ben	Research Assistant	Ph.D., Mechanical Engineering
Yeckel, Andrew	Postdoctoral Fellow	
Yen, Jeng	Research Associate	
You, Yuucheng	Visiting Fellow	
Yuen, David	Faculty Researcher	
Yun, Jie	Research Assistant	M.S., Mathematics
Zachary, Woodford	Faculty Researcher	
Zhang, Ying	Research Associate	
Zheng, Yu-Cheng	Research Assistant	
Zhu, Jian-Gan	Faculty Researcher	