CS 594 – 001
Understanding Parallel Computing

Web page for the course:
http://www.cs.utk.edu/~dongarra/WEB-PAGES/cs594-2006.htm

CS 594 – 001
Wednesday's 1:30 – 4:00

- **Understanding Parallel Computing: From Theory To Practice**
- **Spring 2003 - 3 credits**
  - Jack Dongarra
  - with help from:
    - » George Bosilca
    - » David Cronk
    - » Graham Fagg
    - » Julien Langou
- **Class will meet in Room C211, Claxton Building**

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To Get Hold of Us

- Email: dongarra@cs.utk.edu
  - Room: 413, Claxton
  - Phone: 974-8295
- Office hours:
  - Wednesday 11:00 - 1:00, or by appointment

- TA: Thara Angskun angskun@cs.utk.edu
- 350 Claxton Complex, 974-7622
  - OH: 10am-11am TR, or by request

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Schedule of Topics

- Introduction
- Parallel Programming Models and Machines
  - Shared Memory and Multithreading
  - Distributed Memory and Message Passing
  - Data parallelism
- Build a Cluster
  - Put together a cluster in teams
  - Load software OS, numerical libraries, etc
  - Implement an application
- Sources of Parallelism in Simulation
- Algorithms and Software Tools (depends on student interest)
  - Dense Linear Algebra
  - Sparse matrices
  - Partial Differential Equations (PDEs)
  - Load balancing, synchronization techniques
  - Visualization and monitoring
  - Debugging parallel programs
  - Metacomputing
- Applications (including guest lectures)
- Project Reports
  - On the cluster adventure

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Grades Based on:

- 30% on weekly homework
  (the lowest homework grade will be dropped)
- 30% on a written report and presentation
  (20 pages circa.)
- 30% on a final exam (2 hours)
- 10% on class participation.

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Homework

- Usually weekly
- Lowest grade will be dropped
- Must be turned in on time (no late homework)
- Don't copy someone else's homework.
- Sometimes problems, sometimes programming assignment, sometimes requiring running a program to find the solution.

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Homework (continued)

- We expect an analysis and detailed discussion of the results of your efforts.
  - The program itself is not very interesting.
- Programming in C or Fortran.
- Will go over the assignments the week they are due.
- See class web page weekly for details.

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Using the SInRG Clusters

- Boba Cluster
  - 32 Dell Precision 530s
  - Dual Pentium IV Xeon 2.4 GHz Processors
  - 512 KB Cache
  - 2 GB Ram
  - 2 73GB MAXTOR 6L080J4 Disk Drives
  - On board 3Com Corporation 3c905C NIC
  - Intel e1000 100/1000 NIC
- Frodo Cluster
  - 65 dual AMD-Opteron 240 nodes
  - 2 GB RAM per node
  - Myrinet 2000 interconnect
- Neo Cluster
  - 16 Dual 450MHz UltraSPARC-II 64-bit RISC processors with 4MB L2 cache
  - 512MB (4x128) ECC SDRAM DIMM memory installed
  - SCSI: Integrated dual 40 MB/sec.UltraSCSI channels
  - 27.3GB (1-18GB, 1-9GB) UltraSCSI 10,000 RPM Hard Drives
  - TP Ethernet 10/100BASE-Tt
  - SysKonnect Gigabit Ethernet

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ICL Machines

- 32 node Intel P4 cluster connected with Dolphin Networks
- IBM Power 3s
- Commodity-based Itanium clusters
- SGI Octane
- 64 node Intel EM64T cluster connected with Myrinet 2000
- 64 node AMD Opteron cluster connected with Myrinet 2000

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Project

- Topic of general interest to the course.
- The idea is to read three or four papers from the literature (references will be provided)
- Implement the application on the cluster you build
- Synthesize them in terms of a report (~20 pages)
- Present your report to class (~30 mins)
- New ideas and extensions are welcome, as well as implementation prototype if needed.

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Remarks

- Hope for very interactive course
- Willing to accept suggestions for changes in content and/or form

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Final Exam

- In class
- Will cover the material presented in the course
- ~2 hours

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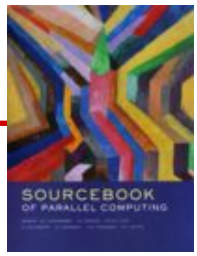
Material



- **Book:**
  - The Sourcebook of Parallel Computing, Edited by Jack Dongarra, Ian Foster, Geoffrey Fox, William Gropp, Ken Kennedy, Linda Torczon, Andy White, 2002, 760 pages, ISBN 1-55860-871-0, Morgan Kaufmann Publishers.
- **For each lecture a set of slides will be made available in pdf or html.**
- **Other reading material will be made available electronically if possible.**
- **The web site for the course is:**
  - http://www.cs.utk.edu/~dongarra/WEB-PAGES/cs594-2006.htm

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Other Sources

- **Will use material from the internet (manuals, papers)**
- **Will use a variety of book sources; including**
  - **Ian Foster**
    - Designing and Building Parallel Programs
  - **Alices E Koniges**
    - Industrial Strength Parallel Computing
  - **Jack Dongarra, Iain Duff, Danny Sorensen, Henk van der Vorst**
    - Numerical Linear Algebra for High Performance Computers
  - **Ananth Gramma et al.**
    - Introduction to Parallel Computing
  - **Michael Quinn**
    - Parallel Programming
  - **David E. Culler & Jaswinder Pal Singh**
    - Parallel Computer Architecture
  - **George Almasi and Allan Gottlieb**
    - Highly Parallel Computing

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Important Place for Software

- Netlib - software repository
  - Go to http://www.netlib.org/

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What will we be doing?

- Learning about:
  - High-Performance Computing.
  - Parallel Computing
  - Performance Analysis
  - Computational techniques
  - Tools to aid parallel computing.
  - Developing programs using PVM, MPI, HPF, and perhaps OpenMP.

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Outline of the Course

1. January 11 Introduction to High Performance Computing
2. January 18 Message Passing
3. January 25 Message Passing continued
4. February 1 Programming and Architectures
5. February 8 Clusters part 1
6. February 15 Clusters part 2
7. February 22 Clusters part 3
8. March 1 Clusters part 4
9. March 8 Memory Hierarchy and Cache
10. March 15 Dense Linear Algebra part 1

March 22 - Spring Break

11. March 29 Dense Linear Algebra part 2
12. April 5 Grid Computing
13. April 12 Iterative Methods in Linear Algebra part 1
14. April 19 Iterative Methods in Linear Algebra part 2
15. April 26 Tools for Debugging and Performance Analysis;
16. May 3 Class Final reports

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What you should get out of the course

In depth understanding of:

- **When is parallel computing useful?**
- **Understanding of parallel computing hardware options.**
- **Overview of programming models (software) and tools.**
- **Some important parallel applications and the algorithms**
- **Performance analysis and tuning**

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Background

- C and/or Fortran programming
- Knowledge of parallel programming
- Some background in numerical computing.

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Computer Accounts

- For much of the class computing you can use one of our set of computer clusters. More on this later
- If you have an account in the Department you have access to the TORC cluster: torc1 through torc8.
- Cluster of PC's:
  - http://icl.cs.utk.edu/iclhelp/ look under clusters

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CS 594 - Understanding Parallel Architectures:
From Theory to Practice

Homework #1
January 11, 2006
Due: January 25, 2006

I would like you to implement a version of the following mathematical operations:

- the 2-norm of a vector,

$$\| x \|_2 = \sqrt{x^T x} = \sqrt{\sum_{i=1}^{n} x_i * x_i}$$

- matrix - vector multiplication,

$$y = y + A * x$$

$$y_i = y_i + \sum_{j=1}^{n} A_{i,j} * x_j, \text{ for } i = 1, \ldots, n$$

- matrix multiplication

$$C = C + A * B$$

$$C_{i,j} = C_{i,j} + \sum_{k=1}^{n} A_{i,k} * B_{k,j}, \text{ for } i, j = 1, \ldots, n$$

The point of this assignment is not to write software, but to look at the performance for each of your implementations and try to explain why you are getting the performance you see and what you could do to increase the performance. You should produce a software implementation for each and run some experiments on various systems, in particular use processors from boba, frodo, and neo clusters. I would like to see a report and analysis of your results, perhaps some plots of your performance data for n between say 10 and 1000. Please verify and convince me that you are computing the correct results in each case. Let me know what computers you used and how you are getting the performance results as well.

Our TA, Thara Angskun, angskun@cs.utk.edu, will have a set of timer you can use to measure the execution time of your programs.

You can find out information on various processors at:
http://www.geek.com/procspec/procspec.htm