University of Minnesota
EE 5371: Computer Systems Performance Measurement and Evaluation
Syllabus, Fall, 2008

	E-mail	Phone	Office	Office Hours
Instructor				
David J. Lilja	lilja@umn.edu	612-625-5007	6-131 EE/CSci	(see class web page)
Teaching Assistant				
Shruti Patil	pati0036@umn.edu	612-624-1845	6-112 EE/CSci	(see class web page)

Class web page: http://www.arctic.umn.edu/ee5371
Time and Location: 2:30-3:45 pm, Tuesdays and Thursdays, 3-125 EE/CSci Bldg., and UNITE.
Credits: 3
Prerequisite: EE 4363/CS 4203 or equivalent (computer architecture); or instructor's permission.

Course Objectives:
- Learn the fundamental techniques for measuring, simulating, and analyzing computer performance.
- Learn to use appropriate statistical techniques to compare systems and interpret measured data.
- Learn how to develop and apply measurement tools and techniques.
- Learn how to use analytical modeling.
- Learn how to appropriately design experiments for performance evaluation.
- Learn how to develop and use various types of simulations.
- Learn to choose an appropriate performance evaluation technique.

Required texts:
1. *Measuring Computer Performance: A Practitioner's Guide,* David J. Lilja, Cambridge University Press, 2000, ISBN 0-521-64670-7 (paperback). (Available at the bookstore in Coffman Union.)
2. Papers from the attached supplemental reading list. These papers are available from the University library through their electronic reserves. Access the papers through this link: http://eres.lib.umn.edu/eres/coursepage.aspx?cid=1323 We will email the password to everyone in the class.

Grading:
Grades will be based on the following items, weighted as shown.

Item	Fraction of grade
Homework	25%
Quizzes	25%
Project proposal	3%
Annotated bibliography	5%
Project poster presentation	10%
Final project report	32%

Letter grades will be assigned according to the following scale:

A	≥	94%	C+	≥	64%
A-	≥	88%	C	≥	58%
B+	≥	82%	C-	≥	52%
B	≥	76%	D+	≥	46%
B-	≥	70%	D	≥	40%
			F	<	40%

In calculating the letter grade breakpoints, the effective 100% mark will be the average of the total scores obtained by the top 5% of the class.

Homework assignments. All homework assignments will be posted on the class web page. No paper copies will be distributed in class.
Quizzes. Several short (20-30 minute) quizzes will be given in class. **There will be no make-up quizzes given.** However, I will throw out the lowest quiz score when computing final grades. UNITE students must arrange with their local coordinators to take the quiz some time during the day it is given to the on-campus students. If that is not possible on a particular day, you will receive a zero for that quiz.
Project. The details of the course project are described in the attached ''Project Requirements.''

General grading policies:
• All assignments are due at the start of class on the indicated due date. Late assignments will receive a reduction of 15% of the maximum possible score for each day they are late, except for documented illnesses and family emergencies.
• Any questions about grading must be brought to the attention of the TA or the instructor within one week after the item in question is returned. Your request must include a short written statement describing your concern.
• You will be evaluated individually to determine your course grade and you are expected to turn in your own work. It is fine if you want to discuss the homework assignments with someone else, but what you turn in for grading should be the result of your own individual efforts.
• All quizzes are to be done individually.
• UNITE students should submit all assignments following the normal UNITE procedures. We cannot accept homework assignments submitted by electronic mail. Contact information for the UNITE office is availabe on their web site: http://www.unite.umn.edu/.

Class E-mail List:
Please add your name to the class e-mail list using the link on the class web page. It is very important that you add yourself to this list since some of the information for this class will be distributed via e-mail.

Computer Accounts:
You will have access to the IT workstation labs for use in this class. See http://www.itlabs.umn.edu/ for information about accessing these workstations. In some of the assignments, I may specify a certain type of machine to use. However, in most cases, you can use any type of machine you want, such as your own PC or a machine available to you through your work, for instance.

Miscellaneous:

• **Incomplete grades.** According to University Senate policy, ‘‘The I grade shall be assigned at the discretion of the instructor when, due to extraordinary circumstances, the student was prevented from completing the work of the course on time. The assignment of an I requires a written agreement between the instructor and student specifying the time and manner in which the student will complete the course requirements. In no event may any such written agreement allow a period of longer than one year to complete the course requirements.’’ The ‘‘extraordinary circumstances’’ must be verifiable. ‘‘Extraordinary circumstances’’ are such things as serious car accidents and major illnesses. They do not include excuses such as ‘‘working too much,’’ ‘‘took too many credits,’’ ‘‘my dog deleted my files,’’ ‘‘I got a great discount on my air travel,’’ and so forth. Furthermore, an ‘‘I’’ can be assigned only when a small portion of the course remains to be completed.
• You are responsible for all assigned readings and all information presented in class, including any changes in due dates, assignments, and so forth.
• You are expected to attend all of the class meetings.
• You are not permitted to submit extra work in an attempt to raise your grade.
• **Academic Integrity and Scholastic Dishonesty.** From the Office for Student Conduct and Academic Integrity (OSCAI): ‘‘Academic integrity is essential to a positive teaching and learning environment. All students enrolled in University courses are expected to complete coursework responsibilities with fairness and honesty. Failure to do so by seeking unfair advantage over others or misrepresenting someone else’s work as your own, can result in disciplinary action.
The University Student Conduct Code defines scholastic dishonesty as follows: Scholastic Dishonesty: submission of false records of academic achievement; cheating on assignments or examinations; plagiarizing; altering, forging, or misusing a University academic record; taking, acquiring, or using test materials without faculty permission; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement.
Within this course, a student responsible for scholastic dishonesty can be assigned a penalty up to and including an ’F’ or ’N’ for the course. If you have any questions regarding the expectations for a specific assignment or exam, ask.’’ For more information, see http://www1.umn.edu/oscai/.
• Students with disabilities that affect their ability to participate fully in class or to meet all course requirements are encouraged to bring this to the attention of the instructor so that appropriate accommodations can be arranged. Further information is available from the Disability Services office.

Expected Course Outline

Topic	Reading*		Approximate number of class sessions
	Text	Papers	
Introduction			
Measurement, simulation, analytical modeling	1	-	1
Performance metrics	2	-	2
Interpretation of measured data			
Measures of central tendency and variability	3	[1-2]	2
Measurement errors and confidence intervals	4, C.1	-	2
Comparing two alternatives	5.1	-	1
ANOVA test	5.2, C.2	-	1
Measurement tools and techniques			
Timing, profiling, and tracing	6	-	1
Benchmarking and Amdahl's Law	7.1-7.2	[3-5]	1
Benchmark programs and benchmark drift	7.3	[6-10]	2
Analytical modeling			
Queueing analysis	11	[11-12]	2
Regression models	8	[13-14]	1
Design of experiments	9	[15-16]	3
Simulation			
Types of simulations	10.1-10.2	[17-19]	2
Random-number generation	B, 10.3	-	2
Verification and validation	10.4, C.3	-	3
Project presentations	-	-	1 †
Quizzes	-	-	2

*Text = Chapter, section, or appendix from the textbook.
Papers = The corresponding paper from the Supplemental Reading List.

Important Dates:

Sep. 16	Quiz 1
Sep. 23	Homework 1 due
Oct. 2	Project proposal due
Oct. 9	Quiz 2
Oct. 14	Homework 2 due
Oct. 28	Quiz 3
Nov. 4	Homework 3 due
Nov. 13	Bibliography due
Nov. 18	Quiz 4
Nov. 25	Homework 4 due
Dec. 9	Quiz 5
Dec. 17†	Project poster presentations and project reports due

† This session will be held in the regular classroom at the final exam time, Wednesday, December 17, 1:30-3:30 pm.

EE 5371: Computer Systems Performance Measurement and Evaluation
Fall, 2008
Supplemental Reading List

Means

1. John R. Mashey, ''War of the Benchmark Means: Time for a Truce,'' *ACM SIGARCH Computer Architecture News,* Vol. 32, No. 4, September, 2004, pp. 1-14.
2. Daniel Citron, Adham Hurani, and Alaa Gnadrey, ''The Harmonic or Geometric Mean: Does it Really Matter?'' *ACM SIGARCH Computer Architecture News,* Vol. 34, No. 4, September, 2006, pp. 18-25.

Amdahl's Law

3. G. M. Amdahl, ''Validity of the Single-Processor Approach to Achieving Large-Scale Computing Capabilities,'' *Proceedings of the Amercican Federation of Information Processing Societies Conference,* AFIPS Press, 1967, pp. 483-485.
4. J. L. Gustafson, ''Reevaluating Amdahl's Law,'' *Communications of the ACM,* May, 1988, pp. 532-533.
5. Mark D. Hill and Michael R. Marty, ''Amdahl's Law in the Multicore Era,'' *Computer*, Vol. 41, No. 7, July, 2008, pp. 33-38.

Benchmark Programs

6. J. L. Gustafson and Q. O. Snell, "HINT: A New Way to Measure Computer Performance," *Hawaii International Conference on System Sciences,* 1995, pp. II:392-401.
7. John L. Henning (ed.), ''SPEC CPU2006 Benchmark Descriptions,'' *ACM SIGARCH Computer Architecture News,* Vol. 34, No. 4, September, 2006, pp. 1-17.
8. John L. Henning, ''SPEC CPU Suite Growth: An Historical Perspective," *ACM SIGARCH Computer Architecture News,* Vol. 35, No. 1, March, 2007, pp. 65-68.
9. Joshua J. Yi, Hans Vandierendonck, Lieven Eeckhout, and David J. Lilja, ''The Exigency of Benchmark and Compiler Drift: Designing Tomorrow's Processors with Yesterday's Tools,'' *International Conference on Supercomputing (ICS)*, June, 2006.
10. Daniel Citron, John Hennessy, David Patterson, and Guri Sohi, ''The Use and Abuse of SPEC: An ISCA Panel,'' *IEEE Micro*, July/August, 2003 Vol. 23, No. 4, pp. 73-77.

Operational Analysis

11. K. Shen, A. Zhang, T. Kelly, C. Stewart, ''Brief Announcement: Operational Analysis of Processor Speed Scaling,'' *ACM Symposium on Parallelism in Algorithms and Architectures (SPAA)*, June, 2008.
12. T. Kelly, K. Shen, A. Zhang, and C. Stewart, ''Operational Analysis of Parallel Servers,'' *IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS),* September, 2008.

Regression Models

13. Neil J. Gunther, ''Performance and Scalability Models for a Hypergrowth e-Commerce Web Site,'' *Performance Engineering - State of the Art and Current Trends,* Lecture Notes in Computer Science, Vol. 2047, Springer-Verlag, 2001, pp. 267-282.
14. P. J. Joseph, Vaswani Kapil, M. J. Thazhuthaveetil, ''Construction and use of linear regression models for processor performance analysis,'' *International Symposium on High-Performance*

Computer Architecture (HPCA), 2006, pp. 99-108.

Design of Experiments

15. Kingsum Chow and Youfeng Wu, ''Feedback-directed selection and characterization of compiler optimizations,'' *Proceedings of the 2nd Workshop on Feedback-Directed Optimization,* 1999.
16. Joshua J. Yi, David J. Lilja, and Douglas M. Hawkins, ''Improving Computer Architecture Simulation Methodology by Adding Statistical Rigor,'' *IEEE Transactions on Computers,* Vol. 54, No. 11, Nov. 2005, pp. 1360-1373.

Simulation

17. Joshua J. Yi, David J. Lilja, Resit Sendag, Sreekumar Kodakara, and Douglas M. Hawkins, ''Speed and Accuracy Trade-offs in Microarchitectural Simulations,'' *IEEE Transactions on Computers*, Vol. 56, No. 11, November, 2007, pp. 1549-1563.
18. T. Sherwood, E. Perelman, G. Hamerly, and B. Calder, ''Automatically Characterizing Large Scale Program Behavior,'' *International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS),* 2002, pp. 45-57.
19. R. E. Wunderlich, T. F. Wenisch, B. Falsafi, J. C. Hoe, ''SMARTS: Accelerating Microarchitecture Simulation via Rigorous Statistical Sampling,'' *International Symposium on Computer Architecture,* 2003, pp. 84-95.