University of Minnesota
EE 5371: Computer Systems Performance Measurement and Evaluation
Syllabus - Fall, 2014

Instructor
David J. Lilja  lilja@umn.edu  612-625-5007  6-131 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 Keller Hall, 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:
3. Papers from the attached supplemental reading list. These papers are available from the University library through the class moodle site: https://moodle.umn.edu/

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Fraction of grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>40%</td>
</tr>
<tr>
<td>Quizzes</td>
<td>20%</td>
</tr>
<tr>
<td>Project poster presentation</td>
<td>5%</td>
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<tr>
<td>Peer evaluations of poster presentations</td>
<td>2%</td>
</tr>
<tr>
<td>Final project report</td>
<td>33%</td>
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</tbody>
</table>
Letter grades will be assigned according to the following scale:

- A  $\geq$ 94%
- A- $\geq$ 88%
- B+ $\geq$ 82%
- B $\geq$ 76%
- B- $\geq$ 70%
- C+ $\geq$ 64%
- C $\geq$ 58%
- C- $\geq$ 52%
- D+ $\geq$ 46%
- D $\geq$ 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 and project 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. Do not send homework assignments directly to me. The UNITE office will keep track of all submissions. Contact information for the UNITE office is available on their web site: http://www.unite.umn.edu/.

**Computer Accounts:**
You will have access to the College of Science and Engineering computer labs for use in this class. See http://cselabs.umn.edu/ for information about accessing these computers. Alternatively, you can use another computer system that is capable of supporting your homework assignments and class projects, such as your own PC or a machine available to you through your work.

**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 and include 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. Otherwise, a withdrawal (W) would be more appropriate.

- 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.

- Additional University policies that affect your participation in this class are available at this web site (there is a link to this site from the class web page):
  http://policy.umn.edu/Policies/Education/Education/SYLLABUSREQUIREMENTS_APPA.html
# Expected Course Outline

<table>
<thead>
<tr>
<th>Topic</th>
<th>Reading*</th>
<th>Papers</th>
<th>Approximate number of class sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>Lilja</td>
<td>Eeckhout</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Measurement, simulation, analytical modeling</td>
<td>1</td>
<td>1.1-1.2</td>
<td></td>
</tr>
<tr>
<td>Performance metrics</td>
<td>2</td>
<td>2.1-2.3</td>
<td></td>
</tr>
<tr>
<td><strong>Interpretation of measured data</strong></td>
<td>Lilja</td>
<td>Eeckhout</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Measures of central tendency and variability</td>
<td>3</td>
<td>-</td>
<td>[3,4]</td>
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<tr>
<td>Measurement errors and confidence intervals</td>
<td>4, C.1</td>
<td>9.1.1</td>
<td>[5]</td>
</tr>
<tr>
<td>Comparing two alternatives</td>
<td>5.1</td>
<td>-</td>
<td>[6]</td>
</tr>
<tr>
<td>ANOVA test</td>
<td>5.2, C.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Measurement tools and techniques</strong></td>
<td>Lilja</td>
<td>Eeckhout</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Timing, profiling, and tracing</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benchmarking and Amdahl’s Law</td>
<td>7.1-7.2</td>
<td>-</td>
<td>[7-9]</td>
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<tr>
<td>Benchmark programs and benchmark drift</td>
<td>7.3</td>
<td>3.1</td>
<td>[10,16]</td>
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<tr>
<td><strong>Performance modeling</strong></td>
<td>Lilja</td>
<td>Eeckhout</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Queueing and operational analysis</td>
<td>11</td>
<td>4.1, 4.3</td>
<td>[11]</td>
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<tr>
<td>Regression modeling</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Design of experiments</td>
<td>9</td>
<td>-</td>
<td>[12]</td>
</tr>
<tr>
<td><strong>Simulation</strong></td>
<td>Lilja</td>
<td>Eeckhout</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Types of simulations</td>
<td>10.1-10.2</td>
<td>5-6</td>
<td>[13]</td>
</tr>
<tr>
<td>Statistical simulations</td>
<td>B, 10.3</td>
<td>7</td>
<td>[14]</td>
</tr>
<tr>
<td>Verification and validation</td>
<td>10.4, C.3</td>
<td>9.1.3</td>
<td>[15-17]</td>
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<tr>
<td><strong>Project presentations</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Quizzes</td>
<td>-</td>
<td>-</td>
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</tr>
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</table>

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

**Important Dates:**

- Sep. 16 Quiz 1
- Sep. 18 Homework 1 due
- Oct. 2 Homework 2 due
- Oct. 7 Quiz 2
- Oct. 21 Homework 3 due
- Oct. 28 Quiz 3
- Oct. 30 Homework 4 due
- Nov. 13 Homework 5 due
- Nov. 18 Quiz 4
- Dec. 2 Homework 6 due
- Dec. 9 Quiz 5
- Dec. 21 Homework 7 due
- Dec. 28 Quiz 6

† This session will be held in a classroom to be determined at the final exam time, Thursday, Dec. 18, 10:30 am - 12:30 pm.
**Project Requirements**

A major portion of your grade in this course will come from your final project (instead of a final exam). This project requires two main components: 1) a measurement study using a real computer system, plus 2) a mathematical or simulation model to explain and validate the measured results. It is important to show some originality in the idea, in the approach, or in the analysis, and to demonstrate proficiency in the use of appropriate measurement, modeling, and data interpretation techniques.

The project can be an individual effort or you can do the project in teams of two people, with my approval in advance. If you choose to do the project in a team, both members of the team will receive the same grade. Furthermore, it is expected that a team project will require twice the total effort of an individual project.

The project will consist of the following parts. (The first two parts will be assigned as part of the homework assignments.)

1. **Proposal.** A 200-300 word proposal describing what you want to do for the project. This proposal should answer at least the following questions:
   
a) What is the tentative title of your project?

b) Who will be doing the project?

c) What will be measured?

d) Why is this an interesting problem?

e) How will you validate the measurements? For example, do you expect to develop an analytical model or a simulation model?

f) What resources are needed for this project?

g) How will you get access to these resources?

2. **Annotated bibliography.** The annotated bibliography is a list of about 12-15 papers that are relevant to your project. For each paper, you must give the complete citation, which includes the names of the authors, the title of the paper, the title of the journal or conference proceedings in which it appeared, the date, and the page numbers. In addition, you must write a 25 word summary for each paper describing its contents and how it is relevant to your project. This summary must not be a simple repetition of the paper’s abstract. Note that you must supply references to peer-reviewed papers from the published literature. A bunch of references to web sites of unpublished material is not appropriate. The goal of this annotated bibliography is to show that you have adequately researched the previous peer-reviewed work that has been done in the area of your proposed project. Be sure to include your name(s) and the tentative title of your project.

3. **Project poster presentation.** During the final exam time, we will have a poster session where everyone can learn about everyone else’s project. Everyone will be assigned a few posters for which you will be expected to provide feedback to the poster presenters. **UNITE students are expected to come to campus to present their posters at the time scheduled.**
Your poster should include a summary of the problem you are studying, why it is an interesting problem, an explanation of the specific measurement technique you used, a description of your validation methodology, a presentation of your results, and a brief summary of what you learned from the project. Every person in your group is expected to contribute to the poster presentation.

There are several links on the class web site to resources with ideas for producing an excellent poster.

4. Final report. Your final report should describe the project and its results using the guidelines below. You will submit an electronic version of your report to the class moodle site. The final project report will be graded using the rubric that will be posted on the class moodle site.

Guidelines for the Project Report

The final report for your project should be written in the style of a journal or conference paper, such as those you will read throughout this course. It should be about 15-20 double-spaced pages long.

Your report must include at least the following:

a) A cover page with a descriptive title, your name(s), student ID number(s), course number, and date.

b) A 150 word abstract clearly summarizing the problem you investigated, why this is an interesting problem, your methodology, and a summary of your main results and conclusions.

c) An introduction precisely stating the problem and explaining why what you’ve done is important and interesting.

d) A summary of previous research in this area, along with an explanation that places your project in the context of what has been done before (i.e. what is different and similar about what you’ve done compared to what has been done before). You must supply citations within the paper to the previous work you summarized in your annotated bibliography, plus any additional papers you think should be included.

e) A thorough description of your methodology.

f) An explanation, interpretation, and validation of your results using appropriate statistical and modeling techniques.

g) A conclusion summarizing what you’ve done and what it means in a broader context.

While you do not have to follow this outline exactly, all of these elements must be included in your paper. You also must include appropriate figures, graphs, and tables to explain your results. Each figure, graph, and table must be directly referenced in the text. For example, you should say something like, "Figure X shows ..." instead of simply inserting the figure into the paper with no explanation. Each figure, graph, and table must have an appropriately descriptive caption.

Project Details and Ideas

As mentioned above, the project must include the following two components:

1. Measurements taken on a real computer system.

You must use measurement tools that are appropriate for the system you are using, and for the types of information you are trying to gather. An example timer that can be used or adapted to most Linux systems is available on the class web page. However, feel free to use other tools as appropriate for
your measurement study. Keep in mind that an important aspect of any computer performance measurement study is to quantify the variation in your measured values using an appropriate statistical technique.

2. **A mathematical or simulation model that can be used to explain and validate the measurement results.**

As discussed in class, every performance study should include at least two different methods to validate the results. In addition to your measurements, your project must also develop an appropriate analytical or simulation model. This model should be used to explain your results and validate that the conclusions you make from your measurements are reasonable and actually make sense. Example analytical models might include a queueing model parameterized with your measured values; a bounds model, such as an Amdahl’s Law-like model; a regression model; identification of key parameter values and distributions; and so forth.

The key thing to remember for the project is that your measurements and your model should be used together to validate and explain your final results and conclusions.

The following list is intended to get you thinking about possible project ideas and should not be considered a complete list of possibilities. You will produce a much better project, and have much more fun doing it, if the project you choose is on a topic that interests you.

- Evaluate one of the power/energy benchmarks on a couple of real systems.
- Analyze the communication parameters of some computer network as a function of some appropriate input parameter, such as system load.
- Analyze the performance of some interesting machine using standard benchmark programs.
- Compare the predictive capabilities of two or more benchmark suites.
- Identify the bottlenecks in some interactive computer system and use this information to tune the system to obtain better performance.
- Measure the performance of a web server and derive an appropriate regression model to predict its performance as a function of request rate.
- Develop a new benchmark to test the throughput and response time of a Web server.
- Determine if there are any redundancies in the programs in a standard benchmark suite.
- Develop a way to classify benchmark programs to help guide users in benchmark selection.
- Perform a bottleneck analysis of a database system and optimally tune its performance.
- Evaluate the typical and maximum capabilities of a specific system component, such as a disk subsystem, a performance accelerator, etc.
- Measure and model the performance capability of a large cloud system.
Supplemental Reading List

Metrics, Means, and Errors

Amdahl’s Law

Workload Selection and Benchmark Programs

Performance Modeling

Design of Experiments

Simulation

**Validation and Verification**

