UNIVERSITY OF MASSACHUSETTS DARTMOUTH

ECE560:
Computer Systems Performance Evaluation

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ECE Dept., Spring 2024

Welcome to ECE560!

- Today's lecture
  - Course Syllabus & Operational Details
  - Introduction to Computer Systems Performance Evaluation (CSPE)
  - Background Survey

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Course Description

- A required course for all CPE majors and an elective for other engineering majors at the graduate level (BS/MS, MS, PhD)
- Prerequisites
  - graduate standing
  - MTH331 (Probability) or equivalent (e.g., ECE384)

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Motivating Example (1)

- A storage system consists of two disk drives sharing a common queue with infinite capacity. The I/O requests arrive to the storage system at the rate of 40 requests per second with *Poisson* pattern. The time to service an I/O request at each disk drive is exponentially distributed with a mean of 45 milliseconds.
  - What is the probability that each disk drive is busy (i.e., average disk drive utilization)?
  - What is the probability that the entire storage system is idle?
  - What is the probability that both disk drives are busy and exactly two I/O requests are waiting in the queue.

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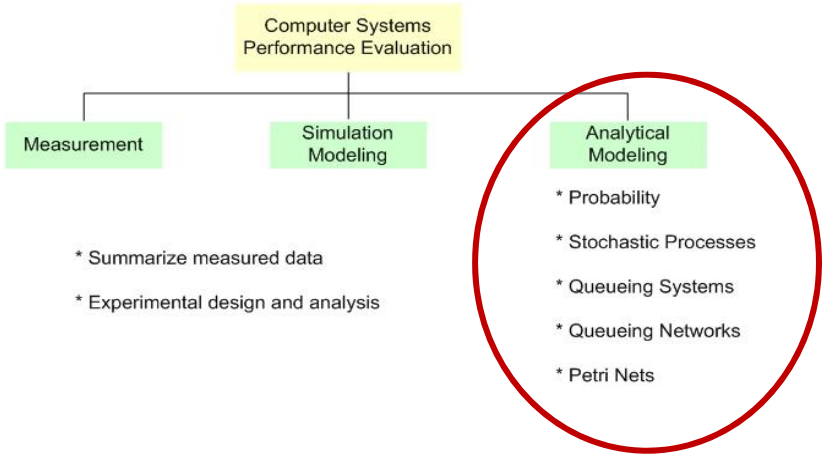
Motivating Example (2)

- A computer information center provides 4 consultants to help personal computer (PC) users solve their problems. PC users with problems arrive randomly with Poisson pattern, at an average rate of 40 per 8-hour day. The amount of time that a consultant spends with a PC user has an exponential distribution with mean value of 30 minutes. Users are assigned to the consultants in the order of their arrival. Assume the center can be modeled as a birth-and-death queuing system with infinite-capacity queue. Determine the following:
  - The percentage of the time each consultant is busy, i.e., average consultant utilization
  - Probability that the information center is not idle.
  - Probability that an arriving user has to wait for service
  - The mean time a user spends in the information center

Course Objective

To introduce students to advanced applications of probability, statistics, queuing theory, and Petri-nets as applied to computer systems performance modeling and assessment.

Course Topics (1)



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Course Topics (2)

- **Introduction** to computer systems performance evaluation.
- **Measurement techniques & tools**: hardware/software /hybrid monitoring, summarizing measured data.
- **Experimental design and analysis**
- **Overview of simulation modeling**
- **Probability theory & statistics** applied to computer systems.
- **Stochastic processes**: counting, Poisson, birth-death, Markov chains, with applications to computer systems.
- **Basic queuing theory**: Kendall notation, Little's law, birth-and-death, embedded Markov-chain queueing systems, and their equilibrium solutions
- **Queuing networks**: open, closed, product-form networks and solutions.
- **Petri nets:** basic, generalized Petri-nets, and their use in modeling computer systems.

Tentative topic outline subject to changes based on class performance & exceptional cases

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Course Outcomes

Upon successfully completing this course, you will be able to

- Demonstrate knowledge of common major techniques for computer systems performance evaluation
- Analyze and evaluate performance of various computer systems using appropriate models and tools
- Develop suitable mathematical representations of systems
- Evaluate design alternatives
- Compare two or more systems
- Appropriately design experiments

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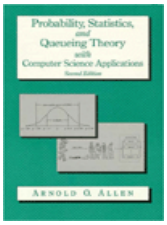
Resources (1)

- **Lecture notes** prepared by Prof. Xing, available from course website
- **Textbook**
  - **A. Allen**, "Probability, Statistics and Queuing Theory: with Computer Science Applications", 2nd Ed., ISBN: 0120510510, Academic Press



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Resources (2)

- **References**
  - R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling", Wiley, John & Sons, 1990.
  - K. S. Trivedi, "Probability and Statistics with Reliability, Queueing, and Computer Science Applications", 2nd Ed., ISBN: 0471333417, Wiley-Interscience, 2001
  - E. D. Lazowska et al., "Quantitative System Performance: Computer System Analysis Using Queueing Network Models", Prentice-Hall. This book is out of print. But the authors have put it on the web (http://www.cs.washington.edu/homes/lazowska/qsp/) for the benefit of public.

Resource (3) - Course Website

- https://xing560.sites.umassd.edu/
  - News and announcements (Recent Posts)
  - Syllabus, Major deadlines,
  - Homework, Project
  - Lecture notes, Exams
  - Frequently asked questions on assignments, exams
  - Check **frequently**!

Course Requirements

Homework

- Complete all assignments on time. Homework are always due by the beginning of class on the due date.
- Assignments one day late subtract 10%; two days late loses 25%; three days late loses 50%. After 3 days the assignments will be considered a ZERO. This penalty rule will be strictly enforced, except for some exceptional cases (**You must inform the instructor ahead of time**!)
- Keep each homework for helping you prepare for the exams
- See website for details about submission
- It's important to do the reading assignments handed out in class

Exams

- Midterm (Tentative time: **March 6, Wednesday**)
- Final (**May 7, Tuesday, 11:30am ~ 2:30pm**)
  - Refer to Final Exam Schedule at: https://www.umassd.edu/registrar/finalexams/
- No early/late-taken exams unless you have a legitimate reason and your absence is excused by your advisor or the student dean
- Unless specifically stated otherwise, grading concerns have expiration date (2 days)

Project

- A performance study of some new computer-based system or architecture idea, a performance study of an existing machine, detailed comparisons of different design alternatives, or some other appropriate topic of your choice
- A list of potential project ideas available from the course website
- **Required work and deadlines**
  - Project proposal due February 23 (Friday)
  - Annotated Bibliography due March 22 (Friday)
  - Project final report due April 19 (Friday)
  - Project presentation on April 22 (Monday) and 24 (Wednesday)

Grading Policy

- **Homework 8%**
- **Project 20%**
- **Midterm 30%**
- **Final 42%**
- **In-class extra-credit problems**

The letter grades will be assigned using the following approximate scale:
(A+, A) [100-90] (A-, B+, B) (90-80] (B-, C+, C) (80-70]
(C-, D+, D) (70-60] (D-) (60-57] (F) [<57]

UMass Dartmouth grading system:
https://catalog.umassd.edu/content.php?catoid=62&navoid=5015#Grades_and_Grading_System

Incomplete Grade Policy

- The incomplete policy for this course is that **at least 70% of the course** must be already completed and an exceptional circumstance (e.g., medical issue) must exist.
- If you feel you require an incomplete grade for an exceptional reason, you need to email me and state your reasons for the incomplete in writing. We will then decide on a course of action.

Cancelled Classes and Exams

- If class is cancelled on the day an exam is scheduled, we will have the exam the next time the class meets.
- If class is cancelled for the session prior to the exam (the day for review and for asking questions), then the next class meeting will be the "review session", and the exam will take place in the class meeting after that.

Attendance Policy

- Students are expected to regularly attend class and all other scheduled activities related to the course.
- The instructor reserves the right to record attendance from time to time (not regularly).
- Students who miss a lecture must self-study the missed material (available from the course website) and make arrangement with the instructor about any questions of the missed lecture when necessary.

COVID-19 Management Policy

- Please follow the health and safety protocols when you come to the campus: https://www.umassd.edu/covid/
- If you test positive for COVID-19, please refer to: https://www.umassd.edu/covid/
- For students who become ill or are required to isolate, please contact me asap; I will respond with information about my expectations for completion of course materials.
- If I test positive but my conditions allow, I will deliver lectures online using Zoom during the isolation; if my conditions require class cancellation or other changes for this course, I will send an email about alternative arrangements to the umassd.edu email account of all class members.

Academic Honesty

- Unless specifically stated otherwise, all homework assignments and exams in this class are to be completed individually. Any collaboration with others or use of work completed by others for previous offerings of this class is considered to be unauthorized aid.
- Furthermore, you should explicitly acknowledge any sources of ideas used that are not your own; this includes other people, books, papers, web pages, etc.

Academic dishonesty will be "rewarded"

with a grade of "F".

https://www.umassd.edu/studentaffairs/studenthandbook/academic-regulations-and-procedures/

In Case Of Trouble

If you feel yourself slipping behind, feel free to meet the instructor for advice. If you do decide the class is not happening for you at this semester,

- the last day to Add/Drop is **Monday, January 29**, and
- the last day to Withdraw is **Friday, April 12**.

However, before you withdraw, please discuss your decision with the instructor and your academic advisor.

In Case of Special Needs

- Please feel free to contact the instructor if you have any special needs that require accommodation.
- Particularly, if you or a family member become sick that affects your submission of an assignment or participation in an exam, please feel free to email me to request an extension to complete the assignment without late penalty or alternative arrangements for the exam.

Academic Support Services

- Academic Resource Center (www.umassd.edu/arc/)
- Engineering Student Support & Services (ES3) (https://www.umassd.edu/engineering/support/)
- STEM Learning Lab (https://www.umassd.edu/arc/stemlearning-lab/)
- Center for Access and Success (www.umassd.edu/dss/)
- Writing &Multiliteracy Center (www.umassd.edu/wmc/)

Title IX Information

- The purpose of a university is to disseminate information, as well as to explore a universe of ideas, to encourage diverse perspectives and robust expression, and to foster the development of critical and analytical thinking skills. In many classes, including this one, students and faculty examine and analyze challenging and controversial topics.
- If a topic covered in this class triggers post-traumatic stress or other emotional distress, please discuss the matter with the professor or seek out confidential resources available from the Counseling Center, http://www.umassd.edu/counselling/, 508-999-8648 or - 8650, or the Victim Advocate in the Center for Women, Gender and Sexuality, http://www.umassd.edu/sexualviolence/, 508-910-4584.
- In an emergency contact the Department of Public Safety at 508-999-9191 24 hrs./day.

Contacting Instructor (1)

- Instructor contact information
  - Email: **lxing@umassd.edu**
  - **Office Hours** (In-person @ SENG213C)
    - Mon. 2:00pm ~ 3:30pm
    - Tue. 11:00am ~ 12:00pm
    - Wed. 2:00pm ~ 3:30pm
    - Or other time by appointment via email.

Contacting Instructor (2)

- Please feel free to contact the instructor if you have any
  - special needs
  - questions about assignments or exams
  - comments, feedbacks on how to improve lectures
  - interesting experiences or tips on how to do well in the class
- Constructive criticism will be appreciated; you may use the following Yahoo email account to send your anonymous feedback to lxing@umassd.edu
  - ID: feedback02747@yahoo.com
  - PWD: feedback4xing

Communication Plan

- Please check the class website frequently (https://xing560.sites.umassd.edu/); the *Recent Posts* section will be used as a primary means of notification of new assignments, deadlines, any class related announcements and information.
- Other than questions asking and answering during the specified office hours, you may also email me with your questions. You can expect a reply from me via email **within 24 hours** during the workweek.
- If the question a student asked is of a nature that even one other student in the course could benefit from the answer, the question and the answer will be posted in the FAQ section of the course website.

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Enjoy the class!

Have A

Fruitful & Joyful

Semester!

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Part II: Introduction to Computer Systems Performance Evaluation (CSPE)

- Why Performance Evaluation (PE)? **Why?**
- PE Measures/Metrics **What?**
- Relevance of Measures to Application Domains
- PE Techniques **How?**
- Selecting a PE Technique
- A Systematic Approach to PE

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Why Performance Evaluation?

- To make sure that the system is suitable for its intended applications
- To make sure that the system satisfies the given efficiency & reliability requirements
- To design/build/operate the system near its optimal level of processing power under the given resource (time, budget) constraints
  - System has *adequate* performance and *reasonable* cost

PE Measures (1: *ECE560*)

- **Responsiveness**: how quickly a given task can be accomplished by system
  - Response time: time to serve a request; elapsed time between the end of an inquiry or demand on a computer system and the beginning of a response (*IBM Dictionary of Computing*)
  - Waiting time, processing time
- **Usage level**: how well various components of system are being used
  - Utilization: indicates percentage of time the resource is busy. The resource with the highest utilization is bottleneck; performance optimization at this resource offers the highest payoff
- **Productivity**: how effectively a user can get work accomplished
  - Throughput: the amount of work finished per unit of time

PE Measures (2: *ECE544 & 620*)

- **Missionability**: indicate if system would remain continuously operational for entire duration of a mission
  - Reliability: probability that the system performs correctly throughout the mission time
  - Useful when repair/tuning is impractical or failure behavior is catastrophic
- **Dependability**: how reliable the system is over the long run
  - Number of failures/day, MTTF, MTTR, long-term availability
  - Useful when repairs are possible and failures are tolerable

ECE544: Fault-Tolerant Computing & Reliability Engineering (Fall)
ECE620: Dependable & Secure Computing (Spring/Fall)
Meet the math requirement for CPE MS

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Relevance of Measures to Application Domains (1)

- General purpose computing
  - Word-processing
  - Responsiveness, usage-level, productivity
- High availability
  - Transaction processing
  - Responsiveness, dependability, productivity
- Real-time control
  - Timing constraints
  - High level responsiveness, dependability

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Relevance of Measures to Application Domains (2)

- Mission oriented
  - Little/no repair is possible during mission, e.g., airplanes
  - High reliability, responsiveness
- Long-life
  - Unmanned spaceships with intelligent built-in diagnostics & repair facility
  - Highly dependable, responsiveness

PE Techniques

- **Measurement**
  - Designing an experiment
  - Measuring performance parameters
  - Data analyzed by statistical techniques to draw meaningful conclusions
- **Analytic modeling**
  - Constructing a mathematical model (Queue, Markov-chain, Petri nets, etc.)
  - Solving it
- **Simulation modeling**
  - Constructing a system behavior model
  - Driving it with an appropriate abstraction of workload
  - Involving experiment design, data gathering & analysis

Selecting a PE Technique (*Pros* & *Cons*)

Criterion	Measurements	Analytical Modeling	Simulation
Life-cycle stage	Post-prototype	Any	Any
Time required	Varies	Small	Medium
Tools	Instrumentation	Analysts	Computer Languages
Accuracy	Varies	Low	Moderate
Trade-off analysis	Difficult	Easy	Moderate
Cost	High	Small	Medium
Salability	High	Low	Medium

Two or more techniques can be used

- simultaneously to verify and validate the results of each one
- sequentially in different stages of evaluation

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A Systematic Approach to PE (1)

1. State goals of study and define the system
2. List system services and outcomes
3. Select performance metrics
4. List parameters that affect performance
5. Select factors (parameters that are varied during study) and their values to study
6. Select evaluation technique
7. Select workload (what is stressing the system, should be representative of the system usage in real life)
8. Design experiments
9. Analyze and interpret data
10. Present results. Start over, if necessary

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A Systematic Approach to PE (2)

Required reading assignment:

A case study (From Jain's book Ch. 2.2):

Remote Pipes vs. Remote Procedure Call

The PDF version of the case study is available from the course website (Lecture Notes section, Relevant Reading column for Lecture 1).

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Summary of Lecture #1

- Course syllabus & operational details
- Introduction to CSPE
  - **Why PE?** To make sure the system can perform the intended function correctly, efficiently, and in a cost-effective manner.
  - **What to measure?** Performance measures and the relevance to application domains.
  - **How to do it?** 3 PE techniques (measurement, analytical modeling, & simulation) and criteria for selecting an appropriate one
  - A 10-step systematic approach to PE
    - A complete project often consists of several cycles through all those steps

Things To Do

- Review the course syllabus
- Read the case study on Remote Pipes vs. RPC
- Check out the class website

https://xing560.sites.umassd.edu/

Next Topic

- Measurement Techniques & Tools

Welcome Again to ECE560 class!