

Carleton University
Department of Systems and Computer Engineering
Design of High Performance Software, Winter 2021
Course Outline

Instructor Information and Office hours

Dr. Gregory Franks, greg@sce.carleton.ca. Please include 5101 in the subject of emails.

Office Hours: See [CULearn](#).

Course Number and Calendar Description

SYSC 5101/ ELG 6111 [0.5 credit]

Design of High Performance Software

Designing software to demanding performance specifications. Design analysis using models of computation, workload, and performance. Principles to govern design improvement for sequential, concurrent and parallel execution, based on resource architecture and quantitative analysis.

Prerequisite(s):

[SYSC 5704](#) (ELG 6174) and a course in software engineering, or equivalent.

Course Objectives

Performance in this course deals with time and capacity characteristics of computer-based systems. When systems are designed for functionality only, the time to complete a response may be so long that the system is ineffective; similarly, its capacity to serve a large number of users may be inadequate making the system uneconomic to use. Both of these problems occur often in practice. Performance engineering that aims at solving these problems is a body of concepts and techniques for evaluating systems and system designs, using measurements and models.

Meeting performance requirements (such as response time, throughput, etc.) is a major concern for all kinds of software products with performance constraints, and especially for real-time systems. Software Performance Engineering (SPE) addresses performance issues throughout the whole software lifecycle and aims to ensure that software products under development will meet their performance requirements. SPE uses predictive performance models to assess different design alternatives at an early stage, before major obstacles to performance are frozen in design and code. This can improve the quality of the final product by helping designers to make informed choices and trade-offs early in the life cycle, when changes are not expensive and open alternatives still exist. As the product evolves, so does the performance model, capturing more system features and producing more accurate results.

The course will cover different basic approaches to performance engineering. Topics will be chosen from measurement techniques, interpreting and comparing results, models that explain capacity constraints and delays (bottleneck models, queueing models and layered queueing models), an introduction to performance-oriented design based on performance principles, patterns and antipatterns.

The goal of this course is to prepare the students to address performance problems in real-time concurrent and distributed systems, such as embedded controllers, enterprise distributed systems, web services-based systems and cloud systems. It will introduce the conceptual framework and the nature of performance problems and solutions, so that the student can apply them into the field.

Learning Outcomes

The main objective/outcome of this course is to teach the students how to use performance modeling techniques and performance engineering tools for design, experimentation, simulation, visualization, and analysis. Concrete learning outcomes are as follows:

Software engineering:

- compute performance bounds for Queuing Network Models;
- apply fundamental operational laws for computing performance measures;
- apply QN and LQN models for analyzing and improving software performance
- understand the meaning of system bottleneck and techniques to alleviate it;
- apply performance principles, performance patterns and antipatterns to improve software performance.

Performance engineering tools

- use performance tools: Java Modelling Tool (JMT), Layered Queueing Networks (LQN)

Textbooks

The following textbook will be the primary reference:

Edward D. Lazowska, John Zahorjan, G. Scott Graham, Kenneth C. Sevcik, "*Quantitative System Performance Computer System Analysis Using Queueing Network Models*", Prentice Hall. (free download from <http://www.cs.washington.edu/homes/lazowska/qsp/>).

Other references (optional):

Daniel A. Menasce, Lawrence W. Dowdy, and Virgilio A.F. Almeida. "*Performance by Design: Computer Capacity Planning By Example*", Prentice Hall. 2004.

Smith, C.U., Williams, L.G.: "*Performance Solutions: A Practical Guide to Creating Responsive, Scalable Software*", Addison-Wesley, Boston. 2002.

Evaluation and Grading Scheme

30% Assignments

40% Project Report

30% Final Exam (Centrally scheduled, 3 hours).

Breakdown of course requirements (assignments, project, exam)

1. **The final exam** will be held during the formal examination period set out in the University Calendar and will be scheduled by Exam Services. The instructor will not accommodate any special requests or alternate arrangements. The final exam is for evaluation purposes only and will not be returned to the student. You will be able to make arrangements with the instructor or with the department office to see your marked final examination after the final grades have been made available. Students who miss the final exam may be granted permission to write a deferred examination (see the Undergraduate Calendar for regulations on deferred exams).
2. **Assignments.** Students are encouraged to discuss issues when working on assignments; however, you are expected to submit your own work for grading (assignments are individual work). There is a fine line between cooperating with your colleagues (discussing problems and ideas) and copying solutions (plagiarism). Not only plagiarism is an instructional offence (see the Graduate Calendar) but doing the assigned work by yourself is by far the best way to prepare for the exam.

Submission: Assignments are due at midnight of the due date and must be submitted online on cuLearn. When submitting assignments, double check that your material has indeed been submitted.

Late assignments will be graded according to the following policy: a cumulative 10% penalty per day (i.e., 24 hours) with a maximum of three days.

3. **Project.** An important part of the course will be a project consisting of an in-depth performance analysis of a system (using QN or LQN models) or a performance engineering research issue. The SYSC 5101 project will be done in teams of two students, that will be constituted at the beginning of the term. Please email me the names of the students who want to work together in a project team as soon as possible. More detailed instructions for the project proposals will be posted in the following weeks.

Week-by-Week breakdown

The following is a tentative outline of the course; it might change, based on time constraints:

1. Performance concepts and requirements.
2. Performance measurement. Workloads.

3. Performance models. Cures for performance problems.
4. Memory hierarchy effects.
5. Queueing Analysis.
6. Software resources.
7. Winter Break. Classes are suspended.
8. Layered resource effects.
9. Measurement and tools.
10. Software Performance Engineering.
11. Software execution models and system execution models.
12. Performance Oriented Design: performance principles, patterns and anti-patterns.
13. Review.

General Regulations

Attendance: Students are expected to attend all lectures and lab periods. The University requires students to have a conflict-free timetable. For more information, see the current *Undergraduate Calendar, Academic Regulations of the University*, [Section 2.1.3, Course Selection and Registration](#) and [Section 2.1.7, Deregistration](#).

Health and Safety: Every student should have a copy of our Health and Safety Manual. A PDF copy of this manual is available online: <http://sce.carleton.ca/courses/health-and-safety.pdf>

Deferred Term Work: Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for making alternate arrangements with the instructor and in all cases this must occur no later than three (3) working days after the term work was due. The alternate arrangement must be made before the last day of classes in the term as published in the academic schedule. For more information, see the current *Undergraduate Calendar, Academic Regulations of the University*, [Section 4.4, Deferred Term Work](#).

Appeal of Grades : The processes for dealing with questions or concerns regarding grades assigned during the term and final grades is described in the *Undergraduate Calendar, Academic Regulations of the University*, [Section 3.3.4, Informal Appeal of Grade](#) and [Section 3.3.5, Formal Appeal of Grade](#).

Academic Integrity: Students should be aware of their obligations with regards to academic integrity. Please review the information about academic integrity at: <https://carleton.ca/registrar/academic-integrity/>. This site also contains a link to the complete Academic Integrity Policy that was approved by the University's Senate.

Plagiarism: Plagiarism (copying and handing in for credit someone else's work) is a serious instructional offence that will not be tolerated.

Academic Accommodation: You may need special arrangements to meet your academic obligations during the term. You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at <http://www.carleton.ca/equity/>. For an accommodation request, the processes are as follows:

- **Pregnancy or Religious obligation:** Please write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see <https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf>
- **Academic Accommodations for Students with Disabilities:** The [Paul Menton Centre for Students with Disabilities](#) (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your **Letter of Accommodation** at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). **Requests made within two weeks of the exam or test will be reviewed on a case-by-case basis.** After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website (carleton.ca/pmc) for the deadline to request accommodations for the formally-scheduled exam (if applicable).
- **Survivors of Sexual Violence:** As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: <https://carleton.ca/sexual-violence-support/>.
- **Accommodation for Student Activities:** Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more

details, see <https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf>

Copyright on Course Materials: The materials created for this course (including the course outline and any slides, posted notes, labs, project, assignments, quizzes, exams and solutions) are intended for personal use and may not be reproduced or redistributed or posted on any web site without prior written permission from the author(s).

Students from the University of Ottawa: You should request to have access to cuLearn: please fill out and submit “Access to CULearn Form” <http://gradstudents.carleton.ca/forms-policies/> .