Fall 2022
SYDE 621 Mathematics of Computation
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SYDE 621 Mathematics of Computation (0.50) LEC

This course provides an overview of solution techniques for a variety of numerical problems encountered by engineers linking with the underlying mathematics and computational trade-offs of various approaches. Given the critical role data play in our present society, topics covered will go beyond traditional examination of mathematics of computation, bringing in relevant and broad-ranging aspects encountered when working in a data-driven world.

Grade Outline (may change depending on time available for different topics):
Assignments   50%
Project   50%

Textbook:
Numerical algorithms: Methods for computer vision, machine learning, and graphics, Justin Solomon, CRC press, 2015

Additional material:
Journal papers will be reviewed and discussed as we go through the material to highlight specific topics

Lectures: Wednesdays 1:30-2:50, Fridays 10:00-11:20

Assignments:
Assignments will be given approximately every other week to enhance understanding of the reading material and class discussions. Completed assignments and code can be handed in using a dropbox on the UW learn page. A late penalty of 10%/day will be applied to the assignments. The instructor needs to be informed of any extenuating circumstances in advance of the due date.

Project:
Students will be able to choose a topic for their project that reflects their interests and/or thesis topic. The topic should build on one of those discussed in course material. Students will be required demonstrate through use of mathematics and numerical computation the solution of their problem. The project should be relevant to the scientific community and draw from a related body of literature. Project proposals (5%) will be due at the end of September. There will be an intermediate progress presentation (5%) after reading week, and a technical report due at the end of the term (35%) and presentation (5%).

Course outline (Preliminary)
1) Mathematical and computational preliminaries
    a. Review of background material
    b. Forward and backward error
    c. Matrix norms and conditioning
2) Regression, least squares and regularization
3) Orthogonalization (including the role in neural networks)
4) Eigenvalue problems and singular value decomposition
    a. Understanding patterns in data
    b. A more complete view of error: total least squares
    c. Non-normal systems and pseudospectra
5) Nonlinear systems
    a. Fixed point iteration and the contraction theorem
    b. Newton's method and variants
    c. Levenburg-Marquardt method
6) Numerical solution of ODEs
    a. Single-step, multi-step and multistage approaches
    b. Relationship and tradeoffs between traditional approaches, recurrent neural networks and neural ODEs
    c. Solution methods for nonlinear systems
7) Numerical solution of PDEs
    a. Introduction to PDEs, types of PDEs, fundamental solution methods
    b. Introduction to calculus of variations and use in solving PDE problems

Academic Integrity:
In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check www.uwaterloo.ca/academicintegrity/ for more information.]

Grievance:
A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline:
A student is expected to know what constitutes academic integrity [check www.uwaterloo.ca/academicintegrity/] to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, www.adm.uwaterloo.ca/infosec/Policies/policy71.htm. For typical penalties check Guidelines for the Assessment of Penalties,

www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

Appeals:
A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.

Note for Students with Disabilities:
The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term