COMP-761: Mathematical tools for computer science

Got math? This is a whirlwind introduction to important math that turns up everywhere in computer science. We will explore many topics. But the goal is really to learn how to reason mathematically about problems in computer science from the ground up - and how to prove statements formally when you need to.

Instructor
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Office hours: Mon 5-6 pm, Fri 10-11 am

Teaching assistant
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Office hours: Thu 10:30-11:30 am

Class times: MWF 4-5 pm

All class meetings and office hours will take place via Zoom. While classes will be recorded, students are expected to attend and participate in all classes live, and attendance is included in the final grade.

Prerequisites: Permission of instructor. This course is aimed at CS graduate students who don't have an extensive background in formal mathematics and are looking to raise their math skills.

Textbooks: None

Detailed syllabus
These topics are tentative and may change slightly depending on timing and student interest. Bear in mind that material will be presented from a mathematical point of view - expect proofs, as well as intuition for why these ideas matter.

1. Introduction
2. Proofs and how to think about problems
3. Proof techniques: Induction
4. Proof techniques: Contradiction
5. Other proof techniques (e.g. monovariants and inequalities)
6. Combinatorics (e.g. binomials, combinatorial identities)
7. Graph theory I (e.g. trees, Hamiltonian cycles, colorings)
8. Linear algebra I (e.g. vector spaces, matrix products, determinants, SVD)
9. Linear algebra II (e.g. matrix norms, random matrix theory)

10. Graph theory II (e.g. random walks, graph Laplacians, spectral graph theory)
11. Calculus I (e.g. limits, derivatives, gradients)
12. Calculus II (e.g. Taylor series, big-O notation, asymptotic analysis)
13. Probability I (e.g. Gaussians, entropy and mutual information, KL divergence)
14. Probability II (e.g. Bayes' theorem, variational inference, Markov Chain Monte Carlo)
15. Linear programs I (e.g. primal and dual formulation, discrete geometry)
16. Linear programs II (e.g. simplex method, ellipsoid method)
17. Semidefinite and quadratic programs
18. Integer programs
19. Spanning trees, shortest paths
20. Maxflow
21. Packing problems
22. Sorting
23. Simple data structures
24. Amortized cost
25. Advanced binary search trees (e.g. splay trees)
26. Heaps
27. Hashing
28. Huffman trees and suffix trees
29. Approximation algorithms I
30. Approximation algorithms II
31. Fast matrix multiplication and FFT
32. The probabilistic method
33. Compressed sensing
34. Information theory
35. Graphical models
36. PAC Bayes
37. Basic neural networks
38. Deep learning theory I
39. Deep learning theory II

Grading

Student evaluations will be evaluated as follows:

- 10%, attendance at class meetings
- 10%, making a diligent effort during participation in class (getting the "right answer" is not important, but thinking is)
- 80%, performance on problem sets - the 5 or 6 problem sets will be weighted equally

Note: An exception may be made for the attendance/participation portions of the grade for those students who are attending the class remotely from a time zone that prohibits live participation. Such students must describe such circumstances to the instructor in advance.

Collaboration policy

Collaboration is an important part of understanding, and talking to fellow students about the problem sets is encouraged. All collaborators must be listed on the submitted solutions.

Written solutions must be completely your own - do not share proofs / Overleaf / written notes etc. with other students. If two collaborators submit material that looks suspiciously similar, both may be given lower marks.

Language of Submission
In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.

Inclusivity
As the instructor of this course I endeavor to provide an inclusive learning environment. However, if you experience barriers to learning in this course, please do not hesitate to discuss them with me or the Office for Students with Disabilities (514-398-6009).