CS 860: Advanced Topics in Algorithms & Complexity Theory
Communication complexity
Winter 2020 Course Outline

Course website: `cs.uwaterloo.ca/~eblais/courses/W20/CS860/`

CS 860 Description

Concentration Inequalities in Computer Science

This course explores the concentration of measure phenomenon. Informally: with a single random variable (say, the flip of one fair coin), then there usually isn't anything about this variable that we can predict with any reasonable confidence. With a large number of independent random variables, however, there are lots of predictions we can make with high confidence (for example, with 10000 coin flips, roughly 1/2 of them will land heads; the longest run of heads or tails will be of length roughly 100; etc.) Concentration inequalities give bounds on the probability that these predictions are wrong.

Concentration inequalities have many deep and surprising implications in the analysis of randomized algorithms and in complexity theory. They are a key ingredient in numerous results in sublinear-time algorithms, compressed sensing, communication complexity, the analysis of Boolean functions, dimension reduction and machine learning, etc. We will explore some of the main concentration inequalities and their applications to various problems in theoretical computer science. Part of the class will explore how the concentration inequalities are established, but the main focus will be to understand how to use these inequalities in a wide variety of different topics within computer science.

Winter 2020 Schedule and Contact Information

Lecture Schedule

Days	Times	Location	
W	10:30am–12:50pm	DC 2568	Eric Blais

Course Staff Contact Information

Eric Blais
(Instructor)
Office: DC 3122
E-mail: `eric.blais@uwaterloo.ca`
Office hours: By request.

Winter 2020 Weekly Calendar

The course will consist of six main modules.

1. **Fundamentals** Markov and Chebyshev inequalities

2. **Basic concentration inequalities** Chernoff and Hoeffding bounds

3. **More basic concentration inequalities** Bernstein inequality, generalized Hoeffding inequalities

4. **Random vectors** Concentration of norm and properties of high-dimensional random vectors

5. **Random matrices** Concentration of norms and properties of high-dimensional random matrices

6. **Beyond sums of independent random variables** Concentration of Lipschitz functions, Matrix Bernstein inequality

7. **Quadratic forms** Decoupling, Hanson-Wright inequality, Symmetrization

8. **Random processes** Introduction

Each week, all students are required to read the corresponding sections of the course textbook before lecture. During lecture, we start with a short quiz about the assigned reading and then solve problems from various areas of computer science using that week's material in small groups. Each student must then submit written solutions to the problem sets by the end of the week.

Grade calculation

The final grades for the class will be determined by a combination of the weekly quizzes and problem sets and the final project, according to the following mark breakdown.

- 50%: Weekly tasks

    - 5%: Quizzes
    - 5%: Class participation
    - 40%: Written assignment solutions

- 50%: Final project

    - 5%: Project proposal
    - 5%: Project proposal presentation
    - 10%: Final presentation
    - 30%: Final project report

Course Work Policies

Assignment Submission

All assignments in this class require written (mathematical) solutions typeset in LaTeX.

Missed or Late Work

Assignments are due by Friday 7pm on the week that they are assigned in class. No late assignments will be accepted.

Special accommodations will be considered in exceptional cases only with appropriate written documentation, such as Verification of Illness Forms (VIF).

Other Important Information

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 the Office of Academic Integrity's website, `www.uwaterloo.ca/academicintegrity/`, for more information.

All members of the UW community are expected to hold to the highest standard of academic integrity in their studies, teaching, and research. This site explains why academic integrity is important and how students can avoid academic misconduct. It also identifies resources available on campus for students and faculty to help achieve academic integrity in – and out – of the classroom.

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, Section 4, `http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm`. When in doubt please be certain to contact the departments administrative assistant who will provide further assistance.

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

Avoiding Academic Offenses. Most students are unaware of the line between acceptable and unacceptable academic behaviour, especially when discussing assignments with classmates and using the work of other students. For information on commonly misunderstood academic offenses and how to avoid them, students should refer to the Faculty of Mathematics Cheating and Student

Academic Discipline Policy, `http://www.math.uwaterloo.ca/navigation/Current/cheating_policy.shtml`.

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, `http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm`.

Note for students with disabilities. AccessAbility Services, located in Needles Hall, Room 1401, 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 AccessAbility Services at the beginning of each academic term.

Mental Health. If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support.

On-campus Resources

- Campus Wellness `https://uwaterloo.ca/campus-wellness/`

- Counselling Services: counselling.services@uwaterloo.ca / 519-888-4567 ext 32655 / Needles Hall North 2nd floor, (NH 2401)

- MATES: one-to-one peer support program offered by Federation of Students (FEDS) and Counselling Services: `mates@uwaterloo.ca`

- Health Services service: located across the creek from Student Life Centre, 519-888-4096.

Off-campus Resources

- Good2Talk (24/7): Free confidential help line for post-secondary students. Phone: 1-866-925-5454

- Here 24/7: Mental Health and Crisis Service Team. Phone: 1-844-437-3247

- OK2BME: set of support services for lesbian, gay, bisexual, transgender or questioning teens in Waterloo. Phone: 519-884-0000 extension 213

Diversity. It is our intent that students from all diverse backgrounds and perspectives be well served by this course, and that students learning needs be addressed both in and out of class. We recognize the immense value of the diversity in identities, perspectives, and contributions that students bring, and the benefit it has on our educational environment. Your suggestions are encouraged and appreciated. Please let us know ways to improve the effectiveness of the course for you personally or for other students or student groups. In particular:

- We will gladly honour your request to address you by an alternate/preferred name or gender pronoun. Please advise us of this preference early in the semester so we may make appropriate changes to our records.

- We will honour your religious holidays and celebrations. Please inform of us these at the start of the course.

- We will follow AccessAbility Services guidelines and protocols on how to best support students with different learning needs.