

C&O 666/466 CONTINUOUS OPTIMIZATION
Fall 2020

Course Homepage: ... is on uWaterloo-LEARN

Lectures: online through the course homepage. Lectures will be released on Tuesdays and Thursdays at 8a.m. (EST).

Instructor: L. Tunçel, e-mail: levent.tuncel@uwaterloo.ca

Office Hours: (Starting on September 14, 2020 and ending on December 7, 2020) Mondays 11a.m.-noon (EST) and Thursdays 7p.m.-8p.m. (EST), or by appointment. Office hours will be held over Zoom. Students are encouraged to submit their questions for office hours ahead of time, by email to levent.tuncel@uwaterloo.ca. There will be a summary/record of each office hour posted on the course website shortly thereafter. Please use only your uWaterloo email account to send me email messages.

TA: Dr. N. Kalantarova, email: n2kalantarova@uwaterloo.ca

Topics Include: We will study fundamentals of *continuous optimization* in Euclidean spaces. For most of the purposes of this course, a *continuous optimization problem* is the problem of minimizing (or maximizing) a given continuous function of finitely many real variables, subject to constraints described as equations and inequalities on some other given continuous functions. Our work will include mathematical foundations, design and analysis of algorithms to solve continuous optimization problems.

- (1) *Introduction:* Notation, formulations, fundamental observations justifying the necessity of identification and exploitation of structure in continuous optimization problems, quick review of some of the relevant fundamental results from linear algebra and real analysis.
- (2) *Unconstrained Continuous Optimization:* Optimality conditions, obtaining derivatives, first and second order algorithms, steepest descent, Newton's Method, quasi-Newton Methods, conjugate gradient method, line search and trust region methods (and a mathematical study of convergence and other fundamental properties of these algorithms).
- (3) *Role of Convexity in Continuous Optimization:* Characterizations of convexity in functions, duality and convex conjugacy (fundamental properties), subgradients and subdifferentials, Lagrange multipliers.
- (4) *Constrained Continuous Optimization:* Existence and uniqueness of optima, first and second order optimality conditions, Karush-Kuhn-Tucker Theorem, local versus global optimization, penalty and barrier methods, gradient projection methods, sequential quadratic programming, augmented Lagrangeans.
- (5) *Complexity Analyses for First-Order and Second-Order Algorithms:* Modern first-order algorithms and their complexity analysis; modern interior-point algorithms and their complexity analysis.

Homework Assignments: There will be five assignments to be submitted via Crowdmark. Late submissions will not be accepted. You may use any clearly quoted results from the lectures or the textbook. Prove all your claims. You may use software packages like Maple, sage, cvx, MATLAB and DDS (Domain Driven Solver) to get ideas or to find and verify counter-examples; however, ideally, your written answers and proofs should be self-contained and be independent of any software.

Personalized Assessments: There will be two personalized assessments (one during October 19–23, 2020 and one during November 23–27, 2020). There are many potential pitfalls in remote education: lack of one-on-one interaction, risk of procrastination, lack of timely feedback. To remedy some of these potential drawbacks, teaching staff will put a lot of effort in this direction. Among these efforts, Personalized Assessments are one-on-one online meetings (approximately 15 minutes for each session) with a member of the teaching staff for co666/466. These meetings will provide one-on-one interaction, and help assess students' personal work on the assignments (including reading assignments). It will also provide an opportunity for students to illustrate how they have learned from the assignments (even on those parts they did not get completely right initially). Further details, examples and logistics will be described on the course website by October 1, 2020.

Final Grade: Homework assignments 16% each. Personal Assessment 1: 8%, Personal Assessment 2: 12%

A missed assignment or a late assignment will be treated the same as a mark of zero unless the cause is illness (a medical note is necessary), or a similar good reason given promptly in writing, in which case the corresponding weight will normally be transferred to the other submitted work (assuming the student does not miss any other assignments).

Textbook: *Numerical Optimization* (by J. Nocedal and S. Wright), 2nd edition, Springer 2006 (pdf available through uWaterloo Library login)

Other References:

- (1) *Convex Optimization* (by S. Boyd and L. Vandenberghe) 2004-... (7th printing, 2009, is available online)
- (2) *Lectures on Convex Optimization* (by Y. Nesterov) 2nd edition 2018 (pdf is available through uWaterloo Library login)

Prerequisites for Undergraduate Students: In addition to cumulative overall average of at least 80%, any one of the following items is sufficient:

- (1) co 255 Introduction to Optimization–Advanced Section (or equivalent)
- (2) co 250 Introduction to Optimization and co 367 Nonlinear Optimization (or equivalent of both)

Students who have no prior exposure to continuous optimization should read Appendices A.1 and A.2 of the textbook (pages: 598–634).

ACCESS ABILITY SERVICES

<https://uwaterloo.ca/accessability-services/>

University of Waterloo has a long standing commitment to support the participation and access to university programs, services, and facilities by persons with disabilities. Access Ability Services office (AAS) is 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.

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

<http://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, Section 4, <http://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 to avoid committing academic offences 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 professor, 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, <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>.

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>.

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.

MENTAL HEALTH SUPPORT

The Faculty of Math encourages students to seek out mental health support if needed.

- On-campus Resources:
 - Campus Wellness <https://uwaterloo.ca/campus-wellness/>
 - Counselling Services: counselling.services@uwaterloo.ca/ 519-888-4567 ext 32655
 - MATES: one-to-one peer support program offered by Federation of Students (FEDS) and Counselling Services: mates@uwaterloo.ca
 - Health Services: located across the creek from the 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