Introduction to the Course

Optimization Techniques (ENGG*6140)

School of Engineering,
University of Guelph, ON, Canada

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Winter 2023

Introduction of the Instructor and Students

Let us know each other by introducing ourselves!

Feel free to let us know (if you would like):

- Your name
- Your major
- Whether you are studying MEng, MASc, or PhD
- What it your goal for taking this course? What are your expectations from this course?
- How much you know about optimization?
- How was your Christmas vacation? :)

Introduction of the Course

- The course provides **the main methods of optimization which can be used in practice**.
- We start with **preliminaries** including sets, norms, functions, local/global minimizer, derivatives, gradient, Jacobian, Hessian, convexity of sets, and convexity of functions.
- We introduce the **standard problems** (e.g., convex problem, linear programming, quadratic programming, semidefinite programming, etc).
- We cover **linear programming** (the **simplex algorithm**) and **integer linear programming** for continuous and discrete linear problems, respectively.
- We introduce the **Karush-Kuhn-Tucker (KKT) conditions** along with the **Lagrangian function** and the **method of Lagrange multipliers**.
- We cover **unconstrained and constrained first-order optimization** which are gradient methods.
- The **unconstrained and constrained second order optimization** techniques, including the **interior-point method**, are covered in order to be able to solve all convex optimization problems (this method also works fairly well on nonconvex problems).
- We cover important **metaheuristic methods** such as genetic algorithm, particle swarm optimization, and simulated annealing.
- [If time allows,] we will also go through **distributed optimization** (such as **ADMM**) in order to solve complex multivariate optimization problems.

The Tentative Schedule of Weeks

Week 1 - 2	
Topics:	Preliminaries (sets, norms, functions, gradient, Jacobian, Hessian, etc). Convexity of sets and functions. Introduction to standard optimization problems.
Week 2 - 3	
Topics:	Linear Programming, the Simplex method, and Integer linear programming.
Week 4 - 5	
Topics:	Karush-Kuhn-Tucker (KKT) conditions, the Lagrangian function, dual variables, primal and dual feasibility, the dual problem, and the method of Lagrange multipliers
Week 6	
Topics:	The midterm exam.
Week 6 - 7	
Topics:	Unconstrained an constrained first-order optimization: gradient descent, line-search, steepest descent, backpropagation and neural networks, stochastic gradient descent, proximal mapping, proximal gradient method, projected gradient method
Week 8 - 9	
Topics:	Unconstrained and constrained second-order optimization: unconstrained Newton's method, equality constrained Newton's method, interior-point and barrier methods, quasi-Newton's methods
Week 10	
Topics:	Metaheuristic optimization: genetic algorithm, particle swarm optimization, simulate annealing, etc.
Week 10	
Topics:	If time allows: distributed optimization: alternating optimization, dual decomposition methods, augmented Lagrangian method, Alternating Direction Method of Multipliers (ADMM).
Week 11 - 12	
Topics:	Group final project presentations.

Course Materials

- Lecture notes will be provided to you.
- Our tutorial paper: [1] [Link]
- Additional resource for interested students: Convex Optimization I and II at the YouTube channel of Stanford University. [Link]
- Additional books:
  - Boyd's textbook (focusing on convexity and the second-order methods) [2] [Link]
  - The books of Yurii Nesterov (mostly focused on first-order optimization):
    - ★ Introductory lectures on convex optimization: A basic course [3] [Link]
    - ★ Lectures on Convex Optimization [4] [Link]
- Research articles in the literature

Course's Websites

- Classes will be online via Zoom. The link will be provided in the CourseLink.
- Discussion chats and questions will be in Microsoft Teams group of the course. The students will be added to the Teams group.
- The course's website is: [Click here]
  `https://bghojogh.github.io/pages/uoguelph/engg-6140-w23/`
- I will probably upload the videos of the classes to my YouTube channel [Click here].
  I will eliminate personal information of students (such as when they introduce themselves) in the videos.

Course Evaluation

- Assignments (20%): Assignments will be posted on CourseLink along with the due dates. They are performed individually. We will probably have three assignments.
- The midterm exam (30%): Date will be around week 6. Details to be discussed in class.
- Course project (40%)
  - Date: Week 6 - 11
  - More details will be discussed in class. Report will be electronic submission due in CourseLink.
  - The number of people in each group will be announced in the class.
  - Pick a topic after 6 weeks.
  - Send me the title and objectives to approve it.
- Group Presentation (10%):
  - Date: Week 11 - 12
  - During class time
- Bonus points: participation in class, participation in the discussions, asking questions, and answering questions.

Course's Goal

- Don't worry much about your marks!
- Focus on understanding the materials of the course.
- Our goal is to learn the important practical optimization techniques, so you can use them in both your **industrial projects** and **academic research**.
- About theory and practice:
  - We will learn **some theory** to understand why these methods work.
  - We will also learn how to use the methods **in practice** for practical usage.

Ask Questions!

- Please ask questions whenever you do not understand something.
- Let the class be discussion-based. I do not want to be the sole speaker. We are gonna learn all together.

References

[1] B. Ghojogh, A. Ghodsi, F. Karray, and M. Crowley, "KKT conditions, first-order and second-order optimization, and distributed optimization: Tutorial and survey," *arXiv preprint arXiv:2110.01858*, 2021.

[2] S. Boyd, S. P. Boyd, and L. Vandenberghe, *Convex optimization*. Cambridge university press, 2004.

[3] Y. Nesterov, *Introductory lectures on convex optimization: A basic course*, vol. 87. Springer Science & Business Media, 2003.

[4] Y. Nesterov *et al.*, *Lectures on convex optimization*, vol. 137. Springer, 2018.