ECE-GY 6233 System Optimization Methods

Fall 2020

Department of Electrical and Computer Engineering
Tandon School of Engineering
New York University

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Course Objective: This course is appropriate for both upper-level undergraduates and graduate students with basic knowledge in matrix theory (linear algebra) and calculus. Optimization is a very important subject which finds applications in many branches of science and engineering, to name a few, economics, computer science, financial engineering, systems engineering, electrical and computer engineering, mechanical engineering. The course aims to equip students with practical optimization methods for solving real-world applications and prepare them for a career in academia and industry. Topics to be covered include linear programming, nonlinear programming, calculus of variations and dynamic programming.

Prerequisites: The course is offered as a first-year graduate level course. Basic knowledge of linear algebra, calculus and differential equations and scientific computing is assumed.

Grading:

Homework: 30%
Midterm Exam: 25%
Final Exam: 30%
Project: 15%

There will be 7 homeworks for this course including one prelim homework that is due on 09/11/20, and a scribing homework. The signup sheet will be available for students to sign up for the lecture they intend to scribe. The exams are closed book. No calculators are needed for the exams.

Academic Integrity:

You should read the School of Engineering's code of conduct:

https://engineering.nyu.edu/sites/default/files/2018-06/code-conduct2-2-16.pdf

and the code of conduct of the university:

https://www.nyu.edu/about/policies-guidelines-compliance/policies-and-guidelines/academic-integrity-for-students-at-nyu.html

Required Text:

[DBa] D. Bertsekas, *Nonlinear Programming*, Athena Scientific, Second Edition, 1999.
[BV] S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004.
Available online at http://www.stanford.edu/~boyd/cvxbook/

[DL] D. Liberzon, *Calculus of Variations and Optimal Control Theory: A Concise Introduction*, Princeton University Press, 2012
Available online at http://liberzon.csl.illinois.edu/teaching/cvoc/cvoc.html

Supplementary Text:

[MI] M. D. Intriligator, *Mathematical Optimization and Economic Theory*, SIAM Classics in Applied Mathematics, 2002.
[LY] D. Luenberger and Y. Ye, *Linear and Nonlinear Programming*, Springer, 2008.
[CZ] E. K. P. Chong and S. H. Zak, *An Introduction to Optimization*, John Wiley & Sons Inc., 4th edition, 2013.

Additional References:

[AF] M. Athans and P. L. Falb, *Optimal Control: An Introduction to the Theory and Its Applications*, Dover Publications Inc., 2007
[DL] D. Luenberger, *Optimization by Vector Space Methods*, Wiley, 1997.
[DBb] D. Bertsekas, *Dynamic Programming and Optimal Control*. Vol. 1 and 2. Nashua, NH: Athena Scientific, 2007.
[AM] B. Anderson and J. B. Moore, *Optimal Control: Linear Quadratic Methods*, Dover, 1990.
[SZ] S. Zlobec, *Stable Parametric Programming*. Vol. 57. Springer, 2013.
[BN] A. Ben-Tal and A. Nemirovski, *Lectures on modern convex optimization: analysis, algorithms, and engineering applications*. SIAM, 2001.
[BEN] A. Ben-Tal, L. El Ghaoui, and A. Nemirovski, *Robust optimization*. Vol. 28. Princeton University Press, 2009.

Course Outline:

1. Linear programming and simplex technique
2. Duality and sensitivity
3. Unconstrained nonlinear optimization
4. Constrained nonlinear optimization
5. Convex optimization
6. Numerical methods
7. Calculus of variations
8. Dynamic programming

Course Schedule (Tentative):

09/04/20	Lecture 1	Introduction and Basic Concepts
09/11/20	Lecture 2	Unconstrained Optimization **(Homework 1)**
09/18/20	Lecture 3	Convex Optimization
09/25/20	Lecture 4	Convex Optimization **(Homework 2)**
10/02/20	Lecture 5	Duality and Linear Programming **(Project Description Due)**
10/09/20	Lecture 6	KKT Conditions **(Homework 3)**
10/16/20	Lecture 7	Numerical Methods I
10/23/20	Lecture 8	Numerical Methods II **(Homework 4)**
10/30/20		**Midterm (Tentative)**
11/06/20	Lecture 9	Numerical Methods III
11/13/20	Lecture 10	Calculus of Variations **(Homework 5)**
11/20/20	Lecture 11	Machine Learning
11/27/20		**Thanksgiving**
12/04/20	Lecture 12	Dynamic Programming
12/11/20		**Selected Project Presentations**
12/18/20		**Final Exam (Project Report Due)**

Project Description:

Students have two options for the project:

Option 1: Choose three references (published after 1970) on a topic of your choice, which have a common theme of relevance to the subject matter of this course. Read these three papers, digest their contents, and write a report (10-20 type-written pages) explaining (in your own words) their contributions. The report should be a critical survey on the contents of the papers as they relate to the common theme, and should indicate possible directions for extensions as you see them. You are also expected to discuss your report in an oral presentation (about 15 minutes) some time during the last two weeks of the semester.

Option 2: Present (in a written report) results of some original research (done by you) on any one of the topics covered in class or listed below. Or develop a numerical algorithm-based software package for optimization solutions, again on a topic relevant to the subject matter of the course, and submit a report that explains the package, and illustrates it on a number of numerical examples (solutions to some game problems). In either case, you will be expected to discuss your report in an oral presentation (about 15 minutes) some time during the last two weeks of the semester.

Due Date for the Final Report: **12/21/20**

Another deadline: By **10/02/20**, you should let me know of your choice (between the two options above), and in case of Option 1 your selection of the three references.

Report Style: The reports should be written in the IEEE journal style. You can find IEEE guidelines as follows:

http://www.ieee.org/publications_standards/publications/authors/authors_journals.html

Research topics include (but not limited to):

- Robust optimization
- Multi-objective programming
- Combinatorial optimization
- Sub-modular optimization
- Stable parametric programming
- Semi-definite programming
- Conic optimization
- Stochastic control and optimization
- Filtering and statistical estimation
- Optimization of large-scale system
- Non-convex optimization
- Non-smooth optimization
- Network optimization
- Decentralized optimization
- Team problems
- Primal-dual methods
- Penalty and barrier methods
- Algorithmic game theory
- Dynamic game theory
- Differential games
- Auction theory
- Mean-field theory
- Optimal control
- Distributed control

- Linear matrix inequality
- Uncertainty quantification
- Risk-sensitive optimization
- Approximate dynamic programming
- Reinforcement learning

Application domains are (not limited to):

- Communication networks
- Information theory
- Compressive sensing
- Wireless communication
- Power and energy systems
- Environmental engineering
- Path planning and robotics
- Financial engineering
- Aerospace applications
- Circuit and system design
- Microeconomics
- Macroeconomics
- Security and privacy
- Neural networks
- Social networks
- Supply chain and management
- Biomedical engineering
- Industrial control systems
- Complex systems and phenomena
- Signal processing
- Pattern recognition and machine learning

Journals for reference (not limited to):

- SIAM Journal on Optimization (SIOPT)
- Mathematical Programming
- Acta Numerica
- Journal of Optimization Theory and Applications
- Automatica
- IEEE Transactions on Automatic Control
- IEEE Transactions on Information Theory
- IEEE Transactions on Networking
- IEEE Transactions on Signal Processing
- IEEE Transactions on Communications
- INFORMS Operations Research