RUTGERS
Rutgers Business School
Newark and New Brunswick

Information Technology
Course Number: 22:544:634
Course Title: Optimization Methods for Machine Learning

COURSE DESCRIPTION

The aim of this course is to provide graduate students in our MITA program and PhD students in quantitative research areas, greater understanding of the optimization methods used in data analysis and machine learning in the era of big data. Our aim is to familiarize graduate students with basic optimization methods for solving supervised machine learning problems, so that they can use these techniques in their professional life and their own research. We will cover the theory and concepts behind various optimization methods for solving machine learning problems.

Course Delivery Mode: Synchronous remote (SR). Office hours will also be held in online sessions. Please check the Canvas website for Zoom/Webex links to online classes and office hours. Unauthorized posting of class materials to online platforms is not allowed and can be subject to legal action where necessary.

Learning Management System: Canvas.

Hardware and software requirements: A webcam and a microphone are needed for class participation and access to online classes. For attending the lectures and doing the assignments, below are the minimum hardware and software recommended by OTIS: Windows10
Professional environment with Office365 (or equivalent) · I5 Processor · 8gb of RAM · 256gb hard drive · 720p webcam · Internal microphone.

The students in need of financial assistance can reach out to RU NB Dean of Students or RU-N CARE Team for help with getting needed hardware.

RBS New Brunswick Students in need of financial assistance can send an email to:

deanofstudents@echo.rutgers.edu

RBS Newark Students in need of financial assistance may submit their request via a form:

https://myrun.newark.rutgers.edu/care-team

Students can also benefit from reviewing:

https://myrbs.business.rutgers.edu/students/learning-remotely

If students have any technology issues, please they should reach out to OTIS help desk at helpdesk@business.rutgers.edu

COURSE MATERIALS

- Main text: S. Boyd and L. Vandenberghe, Convex optimization, Cambridge university press, 2004.

- Supplementary Materials: Hand-written notes and slides that will be provided by the instructor.

Other materials may be posted on Canvas. Please check Canvas (https://canvas.rutgers.edu/) and your official Rutgers email account regularly every day.

LEARNING GOALS AND OBJECTIVES

- This course is designed to help students develop skills and knowledge in the following area(s):

- *Developing skills: Ability to interpret and apply optimization algorithms for solving key supervised machine learning problems arising in data analysis and more generally data science.*
- *Developing knowledge base: Students will get more familiar with elementary optimization methods so that they can use these methods in their own research and professional life. The students will have a good understanding of both the concepts and practice for solving basic optimization problems arising in the machine learning and data science field.*

- Students who complete this course will demonstrate the following:

- *Ability to apply and develop optimization methods for solving machine learning problems arising in the daily business life including but not limited to classification, prediction based on labeled data and non-linear regression problems.*

- Students develop these skills and knowledge through the following course activities and assignments:

- *Students will complete homework assignments, a midterm and a take-home final exam. Lectures will be interactive with students, allowing them to interact with their peers in collaborative class discussions.*

PREREQUISITES

- A good knowledge of undergraduate level linear algebra and calculus techniques for optimization such as matrix computations, optimality conditions and Lagrange multipliers.
- Familiarity with at least one software tool that can be used for numerical computations (such as R, Matlab, Python or equivalent).

ACADEMIC INTEGRITY

I do NOT *tolerate cheating*. Students are responsible for understanding the RU Academic Integrity Policy (http://academicintegrity.rutgers.edu/)

I will strongly enforce this Policy and pursue *all* violations. On all examinations and assignments, students must sign the RU Honor Pledge, which states, "On my honor, I have neither received nor given any unauthorized assistance on this examination or assignment." I will screen all written assignments through *SafeAssign* or *Turnitin*, plagiarism detection services that compare the work against a large database of past work. Don't let cheating destroy your hard-earned opportunity to learn. See business.rutgers.edu/ai for more details.

ATTENDANCE AND PREPARATION POLICY

- Expect me to attend all class sessions. I expect the same of you. If I am to be absent, my department chair or I will send you notice via email and Canvas as far in advance as possible. If you are to be absent, report your absence in advance at https://sims.rutgers.edu/ssra/. If your absence is due to religious observance, a Rutgers-approved activity, illness, or family emergency/death and you seek makeup work, also send me an email with full details and supporting documentation within 5 days of your first absence. Please explain other aspects of your absence policy in detail; it will save you trouble later.

- For weather emergencies, consult the campus home page. If the campus is open, class will be held.

- Expect me to arrive on time for each class session. I expect the same of you. [If you are going to be tardy, then please send me an email to let me know in advance.]

- Expect me to remain for the entirety of each class session. I expect the same of you. [If you are going to leave early, then please send me an email to let me know in advance.]

- Expect me to prepare properly for each class session. I expect the same of you. Please complete all background reading and assignments for the best learning practice and experience.

- Expect me to participate fully in each class session. I expect the same of you. Please stay focused and involved.

FEEDBACK AND RESPONSE EXPECTATIONS

- Email Response Times: I will do my best to return your emails in 3 days please remind me if you do not hear back from me within 3 days. Please also feel free to join designated office hours. For matters that are not personal, such as queries about exam and homework deadlines, please do not email me directly but use the discussion board on the Canvas.
- Graded Materials Return Times: I will strive to have your assignments/exams graded within at most 2 weeks.

- Discussion Board Response Times: I aim to review and grade your posts within 3 days.

CLASSROOM CONDUCT

- The classes will be held virtually in a synchronous fashion.
- Please silence your cell phones during the lecture time.
- No side conversations, sleeping, phone conversations and texting during lectures please.

EXAM DATES AND POLICIES

There is only one final project in this course, the rest consist of homework assignments.

Take-home final project: Date is to be announced. [Comprehensive].

During all exam mentioned above, the following rules apply:
- If you have a disability that influences testing procedures, provide me an official letter from the Office of Disability Services at the start of the semester.
- Your exam will not be accepted unless you sign the Honor Pledge.
- Make-up exam policy: No make-up exams are given under any circumstances.

GRADING POLICY

Course grades are determined as follows:

50% Homeworks
40% Final exam/project
10% Class participation

- There will be 5-7 homeworks assigned once around every two weeks. Homeworks will include programming exercises as well as conceptual questions.
- Extra credit: Extra credit is available for students with excellent class participation.
- Grade posting: The grades will be posted on the Canvas website.
- Grade grubbing: Your final grade is not subject to negotiation. However, if you feel I have made an error, submit your written argument to me within one week of receiving your final grade. Clarify the precise error I made and provide all due supporting documentation. If I have made an error, I will gladly correct it.
- In order to gain experience with technical writing, each student will be required to scribe notes for one week. The notes will be posted on the course website. The notes should be easy to read and understand to a student who may have missed the class. Scribing will count as a part of class participation grade.

COURSE SCHEDULE

Week 1-2: Basics of Nonlinear Optimization

- Convex sets, convex functions.
- Introduction to unconstrained and constrained optimization problems.
- Examples of nonlinear optimization problems: Matrix completion, matrix factorization, least squares, logistic regression, sparse principal component analysis, expectation maximization.

Week 3: Gradient descent (GD) algorithm

- Geometric interpretation.
- Why GD works and when it does not work.
- Strong convexity and condition numbers, choice of the stepsize.
- First-order optimality conditions for unconstrained problems.
- Projected GD for constrained problems. Frank-Wolfe algorithm.

Week 4: Momentum acceleration

- Nesterov and Polyak's momentum techniques, Adam, AdaGrad algorithms.
- Geometric interpretation.

Week 5-6: Duality theory

- Lagrangians, duality theory, KKT conditions.
- Examples from support vector machines, constrained least squares.

Week 7: Empirical risk minimization

- Risk minimization problems, overfitting.
- Sample average approximation (SAA).
- Examples including logistic regression, ridge regression and generalized linear models.

Week 8: Incremental gradient methods and stochastic gradient descent (SGD)

- Motivations behind incremental gradient methods.
- Averaging techniques for SGD.
- Mini-batching.
- Practical implementation details for SGD: random shuffling of data, tuning of SGD parameters, gradient clipping

Week 9: Improving stochastic gradient

- Stochastic accelerated gradient methods and their tuning.
- Variance reduction techniques. Incremental aggregated gradient methods.
- SVRG, SAG, SAGA and SARAH algorithms.

Week 10: Review of the class

Week 11: Coordinate descent (CD) methods

- Cyclic coordinate descent
- Random coordinate descent
- Application: LASSO problems

Week 12: Quasi-Newton Methods

- BFGS, Limited memory BFGS methods and their stochastic variants. Their application to various machine learning problems including deep learning and SVM.

Week 13: Deep learning

- Convolutional neural nets. Back-propagation and the chain rule for learning weights.
- Interpretation of empirical risk minimization problems as a one-layer network.
- Optimization algorithms for deep learning including SGD, quasi-Newton methods and adaptive gradient methods

SUPPORT SERVICES

If you need accommodation for a ***disability***, obtain a Letter of Accommodation from the Office of Disability Services. The Office of Disability Services at Rutgers, The State University of New Jersey, provides student-centered and student-inclusive programming in compliance with the Americans with Disabilities Act of 1990, the Americans with Disabilities Act Amendments of 2008, Section 504 of the Rehabilitation Act of 1973, Section 508 of the Rehabilitation Act of 1998, and the New Jersey Law Against Discrimination. More information can be found at ods.rutgers.edu.

[Rutgers University-New Brunswick ODS phone (848)445-6800 or email dsoffice@echo.rutgers.edu]

[Rutgers University-Newark ODS phone (973)353-5375 or email ods@newark.rutgers.edu]

If you are ***pregnant***, the Office of Title IX and ADA Compliance is available to assist with any concerns or potential accommodations related to pregnancy.

[Rutgers University-New Brunswick Title IX Coordinator phone (848)932-8200 or email jackie.moran@rutgers.edu]

[Rutgers University-Newark Office of Title IX and ADA Compliance phone (973)353-1906 or email TitleIX@newark.rutgers.edu]

If you seek ***religious accommodations***, the Office of the Dean of Students is available to verify absences for religious observance, as needed.

[Rutgers University-New Brunswick Dean of Students phone (848)932-2300 or email deanofstudents@echo.rutgers.edu]

[Rutgers University-Newark Dean of Students phone (973)353-5063 or email DeanofStudents@newark.rutgers.edu]

If you have experienced any form of ***gender or sex-based discrimination or harassment***, including sexual assault, sexual harassment, relationship violence, or stalking, the Office for Violence Prevention and Victim Assistance provides help and support. More information can be found at http://vpva.rutgers.edu/.

[Rutgers University-New Brunswick incident report link: http://studentconduct.rutgers.edu/concern/. You may contact the Office for Violence Prevention and Victim Assistance at (848)932-1181]

[Rutgers University-Newark incident report link: https://cm.maxient.com/reportingform.php?RutgersUniv&layout_id=7 . You may also contact the Office of Title IX and ADA Compliance at (973)353-1906 or email at TitleIX@newark.rutgers.edu. If you wish to speak with a staff member who is confidential and does **not** have a reporting responsibility, you may contact the Office for Violence Prevention and Victim Assistance at (973)353-1918 or email run.vpva@rutgers.edu]

If students who have experienced a temporary condition or injury that is adversely affecting their ability to fully participate, you should submit a request via https://temporaryconditions.rutgers.edu .

If you are a military ***veteran*** or are on active military duty, you can obtain support through the Office of Veteran and Military Programs and Services. http://veterans.rutgers.edu/

If you are in need of ***mental health*** services, please use our readily available services.

[Rutgers University-Newark Counseling Center: http://counseling.newark.rutgers.edu/]

[Rutgers Counseling and Psychological Services–New Brunswick: http://rhscaps.rutgers.edu/]

If you are in need of ***physical health*** services, please use our readily available services.

[Rutgers Health Services – Newark: http://health.newark.rutgers.edu/]

[Rutgers Health Services – New Brunswick: http://health.rutgers.edu/]

If you are in need of ***legal*** services, please use our readily available services: http://rusls.rutgers.edu/

Students experiencing difficulty in courses due to ***English as a second language (ESL)*** should contact the Program in American Language Studies for supports.

[Rutgers–Newark: PALS@newark.rutgers.edu]

[Rutgers–New Brunswick: eslpals@english.rutgers.edu]

If you are in need of additional ***academic assistance***, please use our readily available services.

[Rutgers University-Newark Learning Center: http://www.ncas.rutgers.edu/rlc

[Rutgers University-Newark Writing Center: http://www.ncas.rutgers.edu/writingcenter]

[Rutgers University-New Brunswick Learning Center: https://rlc.rutgers.edu/]

[Optional items that many faculty include:

- Students must sign, date, and return a statement declaring that they understand the RU Academic Integrity Policy.

- Students must sign, date, and return a statement declaring that they understand this syllabus.]
