

## Course Syllabus

# Linear and Integer Programming (CSCI 5654), Spring 2022

## Course Staff

- **Instructor:** Sriram Sankaranarayanan
- Office Hours: To be announced.
- Abhidip Bhattacharyya (PhD student) will be our teaching assistant.
- Dr. Guillaume Berger (postdoctoral researcher and an expert in optimization) will be assisting us, as well.
- **Office Hours:** To be announced.
- Communications: Please use piazza for all communications. Emails may often not receive a prompt reply. If necessary post privately on piazza so that your post may be visible only to the instructor and/or TA.

## Course Information

- Class Timings: Tuesday, Thursday 12:30 - 1:45 PM
- Class Location: ECCR 150
- Pre-Requisites: Calculus I,II + Algorithms + Linear Algebra.

## Syllabus

### Topics Covered

Roughly, we will cover the following topics (some of them may be skipped depending on the time available).

- Linear Programming: Basics, Simplex Algorithm, and Duality.
- Applications of Linear Programming: regression, classification and other engineering applications.
- Integer Linear Programming: Basics, Branch-and-Bound, Cutting Plane Methods.
- Combinatorial Optimization: Basics of approximation algorithms.
- Network flow problems.

- Interior point methods.
- Semi-Definite Programming.

## Textbook

We will use the following **main** textbook for linear programming.

- R. J. Vanderbei, [Linear Programming: Foundations and Extensions](https://vanderbei.princeton.edu/LPbook). [↗](https://vanderbei.princeton.edu/LPbook)  
(<https://vanderbei.princeton.edu/LPbook>)

This book is available online through CU libraries.

Other books that we will use material from (instructor will provide notes to help students).

- Vasek Chvatal, Linear Programming. This is a classic textbook that inspired many (including your instructor).
- Alexander Schrijver, Theory of Linear and Integer Programming. A more mathematically dense presentation but very important text in this topic: highly recommended for students interested in CS theory.

## Schedule

ID	Date	Topics Covered	Book Sections
1	Tu, 1/11	Introduction to Linear Optimization	Ch. 1
2	Th, 1/13	Modeling Optimization Problems with Examples.	
3	Tu, 1/18	The Simplex Method	Ch. 2
4	Th, 1/20	Initialization	Ch. 3
5	Tu, 1/25	Degeneracy	Ch. 3
6	Th, 1/27	Duality	Ch. 5
7	Tu, 2/1	Proof of Strong Duality Theorem	Ch. 5
8	Th, 2/3	Complementary Slackness Theorem, Dual variables and Sensitivity.	Ch. 5
9	Tu, 2/8	Revised Simplex, matrix factorization of the basis	Ch. 6

10	Th, 2/10	Convex Polyhedra and Geometry	See Notes
11	Tu, 2/15	Convex Polyhedra and Geometry	
12	Th, 2/17	Applications # 1: Norms, Regression and Sparse Regression	
13	Tu, 2/22	Regression and Regularization (Ridge/Lasso Regression)	
14	Th, 2/24	Classification, Max-Margin Classification, Some Applications.	
15	Tu, 3/1	Linear Programming and Games	
16	Thu 3/3	Wrap up of Games and Revision for Exam. Spot Exam # 1 (45 minute exam open)	
16	Tu, 3/8	Integer Linear Programming : Basic Algorithms - Branch and Bound	
17	Th, 3/10	Integer Linear Programming: Cutting Plane Algorithms	
18	Tu, 3/15	Ellipsoidal Algorithm for Linear Programming	
19	Th, 3/17	Ellipsoidal Method wrapup	
20	Tu, 3/29	Newton's Method for Optimization	
21	Th, 3/31	Barrier Functions + Path Following Methods	
22	Tu, 4/5	Wrapup of Path Following Methods and Some Analysis	
23	Th, 4/7	Total Uni-modularity: Network Flow Problems, Max. Bipartite Matching.	
24	Tu, 4/12	Network Simplex Algorithm for Transshipment Problem	
25	Th, 4/14	Network Simplex Algorithm: Wrapup	

## Problem Sets

Problem sets will be given to you as problems that you will need to solve. These could be conceptual problems that may ask you to work through some detail of a proof or formulate an optimization problem, but will also be accompanied by a programming component. For instance, we will ask you to formulate a portfolio optimization problem to invest in a set of stocks. You may be asked to formulate the problem, describe the solution and accompanying the assignment, we may give you a dataset and ask you to implement your solution over the given dataset.

**Note** All assignments posted on canvas.

Assignments can be turned in by the subsequent lecture for a 20% penalty.

To be flexible, we will omit **one problem set** with the lowest scores from consideration while computing the overall grade.

## Programming

We would prefer python but many languages support optimization packages for solving linear/integer programming problems, including C/C++, Java and Julia.

## Course Work/Grades

The course work will consist of (a) weekly problem sets that will involve solving algorithmic problems and some coding; (b) spot exams; and (c) final project.

### Problem Sets (40% of the grade)

We will expect to post 8 problem sets.

### Spot Exams (20% of the grade)

We will have 2 spot exams spread out through the semester. They will test material that you have learned and go on for one hour each.

**Spot exam dates and locations will be announced within the first three weeks of the semester**

### Logistics for Exams

The logistics below assume no COVID-19 related disruption. We will adapt them as the situation evolves.

1. The exam will be held on-campus from 6:00 - 7:00 PM in the evening for students who have registered for in-person section. Location will be announced well in advance. Remote students who live near Boulder can join the on-campus exam. This plan may change if COVID-19 impacts our ability to deliver in person instruction.
2. Students who live too far away will need to email the instructor and agree on a setup by week two. For such students, this may involve signing up for a proctoring service.
3. Accommodations such as alternative exam timings will only be provided for students with a letter from the campus disability services or valid documented medical reasons (a doctor's note is needed). Students receiving the accommodation will need to be mindful of the instructor's limited time and the overall resource limitations.

## Final Project (40% of the grade)

A final project will account for 30% of the grade. It will involve working in teams of up to two students who will understand and implement an algorithm beyond what has been covered in class. The project *may be presented in class over a 15-20 minute slot, or submitted as a 20 minute video produced by the students, that can be posted on youtube or someplace accessible to the class.*

### Logistics for Final Project

1. Teams of up to two students and topics will be finalized by April 1, 2020.
2. All projects will be due on April 29, 2022 (tentative date, will be finalized soon). No extensions are possible.
3. In class presentations of projects will be held during last 10 days of the semester and highly appreciated. We expect about 16 projects to be presented.
4. All projects not presented in class, will be posted as a video so that the instructor and course staff may grade them.

More details will be available as the deadline nears.

## Final Grades

Final grades will be calculated using the cumulative scores with the appropriate weightage.

## Collaboration Policy

You are welcome and encouraged to work together in learning the material. However, please read the following statement clearly. Violating the course policy will result in a failing grade in the entire class and a trip to a honor code hearing. It may also debar you from being a TA or RA in the department for at least a semester.

1. **Resources Available To You:** You are allowed to consult the instructor, course staff and classmates. If you worked with your classmates, your assignment must clearly acknowledge who you worked with. When you work with others, you are expected to understand the solution and write it up on your own, in your own words. Same goes for programming assignments.
2. **Resources Forbidden To You:** Googling for a solution, asking students not in the class, posting on stack exchange, or hiring outside help.
3. **Plagiarism is forbidden:** the assignments and code that you turn in should be *composed entirely on your own*. You should not need to consult sources beyond your textbook, class notes, posted lecture slides and notebooks, programming language documentation, and online sources for basic techniques.

Copying, soliciting a solution to a problem from the internet or another classmate constitutes a violation of the course's collaboration policy.

4. **Do not search for a solution online:** You may not actively search for a solution to the problem from the internet. This includes posting to sources like StackExchange, Reddit, Chegg, etc.

5. **StackExchange Clarification:** Searching for basic techniques in Python, Pandas, or Numpy is totally fine. If you want to post and ask “How do I group by two columns, then do something, then group by a third column” that's fine. What you cannot do is post “Here's a question about optimization (which is the same question you were asked to solve in class)”. That's clearly cheating!

6. **When in doubt, ask:** We have tried to lay down some rules and the spirit of the collaboration policy above. However, we cannot be comprehensive. If you have doubts about this policy or would like to discuss specific cases, please ask the instructor. **If it has not been described above, you should discuss it with us first**

## Standard Course Policies

### Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on [classroom behavior](http://www.colorado.edu/policies/student-classroom-and-course-related-behavior) and the [Student Conduct & Conflict Resolution policies](https://www.colorado.edu/sccr/student-conduct).

### Requirements for COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to [Student Conduct and Conflict Resolution](https://www.colorado.edu/sccr/). For more information, see the policy on [classroom behavior](http://www.colorado.edu/policies/student-classroom-and-course-related-behavior) and the [Student Code of Conduct](http://www.colorado.edu/osccr/). If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the [Public Health Office](#) <sup>↗</sup> (<https://www.colorado.edu/health/public-health/quarantine-and-isolation>) ([contacttracing@colorado.edu](mailto:contacttracing@colorado.edu) (<mailto:contacttracing@colorado.edu>)). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the [Public Health Office](#) <sup>↗</sup> (<https://www.colorado.edu/health/public-health/quarantine-and-isolation>) ([contacttracing@colorado.edu](mailto:contacttracing@colorado.edu) (<mailto:contacttracing@colorado.edu>)).

## Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#) <sup>↗</sup> (<https://www.colorado.edu/disabilityservices/>). Contact Disability Services at 303-492-8671 or [dsinfo@colorado.edu](mailto:dsinfo@colorado.edu) (<mailto:dsinfo@colorado.edu>) for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) <sup>↗</sup> (<http://www.colorado.edu/disabilityservices/students/temporary-medical-conditions>) on the Disability Services website.

## Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

## Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code ([honor@colorado.edu](mailto:honor@colorado.edu) (<mailto:honor@colorado.edu>)); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the [Honor Code website](https://www.colorado.edu/osccr/honor-code) [↗](https://www.colorado.edu/osccr/honor-code) (<https://www.colorado.edu/osccr/honor-code>).

## Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email [cureport@colorado.edu](mailto:cureport@colorado.edu) (<mailto:cureport@colorado.edu>). Information about university policies, [reporting options](https://www.colorado.edu/oiec/reporting-resolutions/making-report) [↗](https://www.colorado.edu/oiec/reporting-resolutions/making-report) (<https://www.colorado.edu/oiec/reporting-resolutions/making-report>), and the support resources can be found on the [OIEC website](http://www.colorado.edu/institutionalequity/) [↗](http://www.colorado.edu/institutionalequity/) (<http://www.colorado.edu/institutionalequity/>).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](https://www.colorado.edu/dontignoreit/) [↗](https://www.colorado.edu/dontignoreit/) (<https://www.colorado.edu/dontignoreit/>).

## Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

See the [campus policy regarding religious observances](http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams) [↗](http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams) (<http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams>) for full details.