ESI 6417: Linear Programming & Network Optimization
Spring 2021
Instructor: Aleksandr M. Kazachkov

Overview

Credits	3 (no pass/fail allowed)
Time	Tuesdays and Thursdays, 9:35–11:05am ET (pds. 3–4), starting Jan. 12, 2021
Location	ufl.zoom.us/j/91979933355, password: dantzig
Website	Canvas through elearning.ufl.edu
T.A.	No teaching assistant

Instructor: Prof. Aleksandr M. Kazachkov

Pronouns	he/him/his
Email	akazachkov@ufl.edu (see Communication Guidelines below)
Office	Virtual, same link and password as for lectures
Office hours	Mondays and Wednesdays, 4:00–5:00pm ET, or by appointment via email
Phone	+1.352.273.4902

Syllabus Contents

1   Course Description and Objectives

> **Catalog Description**   **3 Credits (Letter Grade)**
>
> Formulation and solution techniques for network flow and linear programming problems. Algorithms for network optimization. The simplex method, theory and computation. Duality theory, sensitivity analysis.
> **Prerequisite:** matrix theory.

Instructor's Description of the Class   This PhD-level course provides a mathematically rigorous treatment of theoretical and algorithmic topics in linear programming and network optimization. Students taking this course should already feel comfortable with linear algebra, writing mathematical proofs, and coding simple programs.

Learning Outcomes   By the end of this course, you will be expected to:

- precisely define optimization (and related) terms, such as solution, feasible, optimal, extreme point, vertex, dimension, face, facet, (convex) polyhedron, cone, polar, etc.

- formally state classical mathematical optimization results including the Weyl-Minkowski theorem, Hahn-Banach separation theorem, Farkas lemma, Fourier-Motzkin elimination, and characterizations of total unimodularity.

- prove optimality conditions for linear programming problems through complementary slackness, weak duality, and strong duality.

- analytically and geometrically explain the differences between the primal and dual simplex methods, as well as interior point methods.

- identify when and why certain classes of network optimization problems are guaranteed to provide solutions satisfying integrality conditions, without explicitly imposing them.

- formulate mathematical models and solve them using optimization software.

The course objectives will be pursued through exercises in various forms to help you understand and communicate these concepts, including assignments asking you to prove theoretical results, implement mathematical models, and a final project featuring peer learning.

2   Guidelines on Communication and Class Meetings

Communication Guidelines
Canvas   Please use Canvas Discussions to ask all nonconfidential course questions.
Email   Emails to me regarding this course should have "[**ESI6417**]" in the beginning of the Subject line, so I can more quickly answer your email.

COVID-19, Virtual Section, and Hybrid Section Guidelines
This course will be primarily virtual, though all students enrolled in the *hybrid section* (class 25586 section 1HYB, as opposed to 26968-141D) will be required to present their final projects in person at the end of the semester. Class sessions may be audiovisually recorded and made available for private review. You are not permitted to distribute these recordings to anyone not enrolled in this class. **If you participate in class, you acknowledge that your voice and potentially your image may be captured on this recording. If you do not consent, you must let me know as soon as possible, to discuss alternatives.**

   If you need to schedule a face-to-face meeting for any reason, please reach out to me over email. You will need to wear an appropriate face covering for the entirety of our meeting.

3   Tentative Course Schedule

Wk	Day	Topics*	Assignments	
1	Jan 12	Terminology and history		
	Jan 14	Linear programming basics & LaTeX tutorial	HW 0 out (ungraded)	
2	Jan 19	Optimization modeling in Julia / JuMP		
	Jan 21	Representing polyhedra		
3	Jan 26	Fourier-Motzkin elimination	HW 0 due	
	Jan 28	Farkas's lemma variants		HW 1 out
4	Feb 02	Polarity		
	Feb 04	Simplex method 1: Geometry		
5	Feb 09	Simplex method 2: Primal & Dual		
	Feb 11	Sensitivity analysis	HW 1 due,	HW 2 out
6	Feb 16	Dantzig-Wolfe decomposition		
	Feb 18	Benders decomposition		
7	Feb 23	*Class-selected topic*	HW 2 due	
	Feb 25	**No class: Spring Recharge Day**		
8	Mar 02	Interior point methods		
	Mar 04	Linear programming extensions		**Midterm out**
9	Mar 09	Introduction to graphs and networks		
	Mar 11	Network flow problems	**Midterm due**, HW 3 out	
10	Mar 16	Matching problems 1: Theory		
	Mar 18	Matching problems 2: Algorithms		
11	Mar 23	Shortest path problems	HW 3 due,	HW 4 out
	Mar 25	Linear programs with integral solutions		
12	Mar 30	Basics of integer programming		
	Apr 01	Cutting planes 1: Gomory	HW 4 due	
13	Apr 06	Cutting planes 2: Disjunctive		
	Apr 08	Project presentations		HW 5 out
14	Apr 13	Project presentations		
	Apr 15	Project presentations		
15	Apr 20	Project presentations	**Project due**	
	Apr 22	Reading days		
16	Apr 26	Exam week	HW 5 due,	**Final out**
	Apr 30	Exam week	**Final due**	

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*Subject to change.

4   Class Materials

There is no required textbook or materials & supplies fee. I suggest the following references:

- Arkadi Nemirovski, *ISyE 6661 Lecture Notes: Introduction to Linear Optimization*, 2016. https://www2.isye.gatech.edu/~nemirovs/OPTILectureNotes2016.pdf

- Alexander Schrijver, *Theory of Linear and Integer Programming*, Wiley, 1997. ISBN: 978-0-471-98232-6. https://www.wiley.com/en-us/Theory+of+Linear+and+Integer+Programming-p-9780471982326

- Dimitris Bertsimas and John N. Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific, 1997. ISBN: 1-886529-19-1. http://athenasc.com/linoptbook.html

  Other references that you might find useful for different perspectives:

- Jean-Baptiste Hiriart-Urruty and Claude Lemaréchal, *Fundamentals of Convex Analysis*, Springer, 2001. ISBN: 978-3-642-56468-0. https://link.springer.com/book/10.1007/978-3-642-56468-0

- Jon Lee, *A First Course in Linear Optimization*, 3rd Edition (Version 3.12), Reex Press, 2013–19. https://github.com/jon77lee/JLee_LinearOptimizationBook

- Craig A. Tovey, *Linear Optimization and Duality: A Modern Exposition*, Taylor & Francis, 2020. ISBN: 978-1-315-11721-8. https://www.taylorfrancis.com/books/linear-optimization-duality-craig-tovey/10.1201/9781315117218

- Robert J. Vanderbei, *Linear Programming: Foundations and Extensions*, 5th Edition, Springer, 2020. ISBN: 978-3-030-39415-8. https://link.springer.com/book/10.1007/978-3-030-39415-8

You are expected to take your own class notes, but any slides that are prepared for the course will be made available to you. These are not intended to replace the actual lecture, but rather to serve as an outline. *Any material I distribute to the class should be kept strictly within this class; without my express permission, you cannot share course content (aside from this syllabus) to anyone not enrolled in the class.*

Software Use   We will use the coding language Julia in conjunction with the mathematical modeling language JuMP. It will be helpful to learn to use Jupyter notebooks. All faculty, staff, and students of the University of Florida are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

5   Grading Policy, Assignments, Exams, and Effort

Your course grade will be based on these criteria:

Homework	15%
Midterm Exam	30%
Final Exam	25%
Project	25%
Participation	5%

Participation will be based on in-class and Canvas discussions, and I highly encourage active involvement in both. You should expect to spend, on average, about 6–8 hours on this class per week, outside of lectures.

The (tentative) grading scale is: A = [93,100], A⁻ = [90,93), B+ = [87,90), B = [83,87), B⁻ = [80,83), C+ = [77,80), C = [73,77), C⁻ = [70,73), D+ = [67,70), D = [63,67), D⁻ = [60,63), E = [0,60). Some assignments or exams may be curved if the average is too low. See also the Graduate Academic Regulations on Grading at catalog.ufl.edu/graduate/regulations.

5.1   Attendance

Attendance is not mandatory but advised.

5.2   Homework

You must submit your own homework. You *are* allowed to discuss problems with other students in the class, such as on Canvas, and you may refer to online resources, but you *cannot* share complete answers with each other. However, I strongly encourage you to first sincerely attempt each problem on your own, and to *learn* from any external references you consult. **You *must* properly attribute your sources** at the start of your solution to each problem. For example, if Bob asks Alice for advice on question 3, then Bob would write at the beginning of his solution to question 3: "Attribution: Discussed question 3 with Alice" and "Attribution: self" otherwise. You will not lose points for telling the truth.

I will provide a LaTeX style file for homework submissions. You must, relatively rigorously, show the steps by which you arrived at your solutions. I prefer that you use full sentences, each solution starts on a new page, and the question is repeated before each solution.

Late Assignment Policy For all but the last homework, late submissions are allowed with no penalty for up to a week after the official due date, but their grading may be substantially delayed. Any assignments submitted more than 7 days after the due date will not be graded. Special arrangements will be made in the event of an *excused absence*. Excused absences must be in compliance with University policies in the Graduate Catalog (catalog.ufl.edu/graduate/regulations) and require appropriate documentation.

5.3   Midterm and Final Exams

There will be a midterm and a final exam, both of which will be *take-home* exams. You are not allowed to consult other people or any online sources for the tests, but you are permitted to use your class notes. Please check the course website for the latest exam schedule.

Exam Make-Up Policy   If you are unable to take an exam due to a family or medical emergency, and you notify the instructor in advance of the exam, then a make-up exam will be organized as soon as it is feasible for both you and the instructor.

5.4   Project

In the course project, you will choose an advanced topic related to the class material, give a lecture on this topic to the class, and submit an associated writeup. Checkpoints will be due throughout the semester. I will provide example topics that you can choose, but you may suggest a different subject based on your research interests, subject to my approval.

5.5   Regrade Policy

Every student may request a regrade of their assignments and exams. Only one regrade will be considered per assignment/exam. The deadline for requesting a review is two weeks after the graded work is returned to the class, even if you were not present that day. The request for regrading must be done in writing together with a detailed description of the reasons why you believe there was a mistake in your grade. Note that requesting a regrade implies that the *entire* assignment may be reviewed. This means points could actually be *deducted*.

6   Honor Code

All course participants (myself and students) must abide by the requirements and spirit of the University of Florida Student Honor Code, which can be found at

 https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/.

Every University of Florida student is subject to the following Honor Pledge:

> We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity by abiding by the Student Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment."

You are obligated to report any condition that facilitates academic misconduct to appropriate personnel. Any honor code violations will be handled by the University's honor code process.
    In this course, collaboration on exams is expressly forbidden, as is the exchange of complete answers to homework assignments prior to submission. Please ask if at any point you need me to clarify what my expectations are regarding the honor code, or if there is any other way in which I can help you in complying with the honor code.

7   Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback is available at `gatorevals.aa.ufl.edu/students`. Students will be notified when the evaluation period opens, and can complete evaluations through the

email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via `ufl.bluera.com/ufl`. Summaries of course evaluation results are available to students at `gatorevals.aa.ufl.edu/public-results`.

8   Special Accommodations

If you require any special accommodations, you should contact me as soon as possible to discuss what I can do to ensure accessibility for you, and you should connect with the Disability Resource Center by visiting `disability.ufl.edu/students/get-started`.

9   Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see the Notification to Students of FERPA Rights and visit `registrar.ufl.edu/ferpa`.

10   Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. We aspire to educate students to become future leaders capable of creating diverse and inclusive work cultures wherever their careers may take them.

It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. If you feel like your performance in class is being impacted by discrimination or harassment of any kind please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, `rbielling@eng.ufl.edu`
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, `taylor@eng.ufl.edu`
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, `nishida@ufl.edu`

11   Land Acknowledgement

A Land Acknowledgement is a formal statement that recognizes and respects Indigenous Peoples as traditional stewards of this land, as well as their enduring relationship with it. Specifically, the University of Florida is located on the traditional territory of the Timucua and Seminole tribes. It is important to recognize and reflect on the context in which our (land grant) institution of higher learning exists, and that we are not only acknowledging the history, but also identifying an ongoing process of marginalization and colonialism. I encourage you to read the history of Indigenous Peoples in Florida and the rest of the United States, and consider what you can do to support current indigenous populations.

12   Campus Resources

12.1   Health and Wellness

Take care of yourself by paying attention and devoting time to your physical and mental wellbeing. Do not hesitate to reach out to me or a qualified professional if you are ever in need of support. Resources that are available to you include:

- University Police Department: 352-392-1111 (call 911 for emergencies).

- U Matter, We Care: If you or someone you know is in distress, please contact umatter@ufl.edu or call 352-392-1575 (a nighttime and weekend crisis counselor is available). The U Matter, We Care Team can help connect students to many other helping resources available including, but not limited to, Victim Services, Housing Staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. `https://umatter.ufl.edu`

- Counseling and Wellness Center: Visit the center or call 352-392-1575 for information on crisis and non-crisis services. `https://counseling.ufl.edu`

- Student Health Care Center: Visit the SHCC website or call 352-392-1161 for 24/7 information to help you find the care you need. `https://shcc.ufl.edu`

- UF Health Shands Emergency Room / Trauma Center: For immediate medical care call 352-733-0111 or go to the emergency room at 1515 SW Archer Road, Gainesville, FL 32608. `https://ufhealth.org/uf-health-shands-emergency-room-trauma-center`

- **Sexual Discrimination, Harassment, Assault, or Violence** If you or someone you know has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence, contact the Office of Title IX Compliance, located at Yon Hall Room 427, 1908 Stadium Road, 352-273-1094, `title-ix@ufl.edu`. `https://titleix.ufl.edu`

- Sexual Assault Recovery Services (SARS): Sexual assault counseling available through the Student Health Center, 352-392-1161.

12.2   Academic Resources

- E-learning technical support: 352-392-4357 (option 2) or `learning-support@ufl.edu`.

- Career Resource Center: Career assistance and counseling, Reitz Union, 352-392-1601.

- Library Support: Receive assistance with using the libraries or finding resources.

- Teaching Center: General study skills and tutoring, Broward Hall, 352-392-2010 or 352-392-6420.

- Writing Studio: Help brainstorming, formatting, and writing papers, 302 Tigert Hall, 352-846-1138.

- The Care Area: Address student complaints, create success plans and ongoing support for students in distress, and help students complete necessary medical petition paperwork for all courses or medical withdrawals from a course.

- Distance Learning Complaints: Student complaints for online distance learning programs.