January 5, 2023

INEG 5613- Introduction to Optimization Theory
Online Course Syllabus (Spring 2023)

Instructor:
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Telephone: cell/text (479) 236-6402
Preferences: Email for short, easy-to-state questions and homework submissions
Cell phone [times pre-agreed by email] for less structured questions
[9am to 9pm U.S. Central time, 7 days]

Course Schedule Spring 2023 (8W1):
Jan 16 – Mar 12

Description
Graduate-level introduction to the foundational rationales of numerical optimization methods and model forms including linear programming, integer programming, network flows, and discrete dynamic programming. Model formulation and tractability, search strategies, characterization of optimal solutions, duality and sensitivity, outcome justification. Prerequisite: Graduate standing.

Emphasis
Although development will include frequent formulation and solving of example cases, emphasis is on developing intuition about algorithmic strategies and underlying theory. Students will learn how and why various algorithms and analysis tools work, how model forms affect performance, and which application settings are best suited to each. The goal is to provide the background students need to conduct sound optimization studies and to succeed in later coursework involving either applied optimization topics or deeper theoretical issues.

Required Background
Some familiarity with **matrix algebra** (vector/matrix representation of linear equation systems), and with formulation of elementary optimization models. (See text Primers 1, p.89, and 3, p.203), and also some experience with **formulation of elementary optimization models** (per text Section 2.1).

Required Text
Ronald L. Rardin, *Optimization in Operations Research,* **2nd Edition,** Pearson, 2016. (Numerous topics, homeworks and exams will sync to the 2nd edition, so the 1st edition is **not** a satisfactory substitute.)

Software Usage and AMPL Software

There will be **no need for programming** in C++, Java or similar general-purpose languages, but students will be required to make use of **AMPL commercial optimization software**. Notes on how to access AMPL are provided in documents posted within Blackboard for Block A. The item **AMPL Access Instructions for On Campus Use** relates to using AMPL on campus computers. An option is also available for students to download the **AMPL Code Student Download** file provided there and then run AMPL on their own computers per the given **AMPL Student Download Instructions.**

Course Structure and Outline

The course will be divided into 2 halves – one covering introductory material and Linear Programming optimization, and the second addressing Integer Programming and related material on Network Flows and Dynamic Programming. Each half consists of several major **blocks** of material, offered in 1-4 online lecture **modules**, followed by a **Midterm Exam**. The following two tables show the blocks, modules, assigned text materials, and approximate schedule for each half. The instructor reserves the right to make modest adjustments as the course evolves.

WEEK	BLOCK		MODULE		TEXT MATERIALS
1 Jan 16-22	A	Startup	1	Introduction	Syllabus, 2.1
			2	Graphic solution and outcomes	2.2
			3	Indexing, MP forms and computer solution	2.3-2.5, 2.7-2.8
2 Jan 23-29	B	Search & Convexity	1	Improving search	3.1-3.2
			2	Algebraic conditions for improving and feasible directions	3.3
			3	Linearity, convexity and global solutions	3.4
	C	LP Modeling	1	Modeling of LPs	4.1-4.5
3 Jan 30 – Feb 5	D	LP Structure & Optima	1	LP optimal solutions	5.1
			2	LP standard form, basic solutions and extreme-point solutions	5.2
	E	Simplex Search for LPs	1	Rudimentary simplex	5.3
			2	Sufficiency, degeneracy, cycling and finiteness	5.6-5.7
4 Feb 6-12	F	Duality & Sensitivity	1	Qualitative sensitivity	6.1-6.2
			2	Quantitative sensitivity and dual definition	6.3
			3	Complementary slackness, what if questions, and multi-form dual taking	6.4-6.5
5 Feb 13-19	G	Primal vs Dual & KKT Optimality	1	Primal to dual relationships	6.7 (pp. 344-350)
			2	LP optimality conditions and Primal strategy	Rest of 6.7
	MIDTERM 1 (three hours arranged within Feb 16-19)				

WEEK	BLOCK		MODULE		TEXT MATERIALS
6 Feb 20-26	H	IP Modeling	1	Modeling of ILPs	11.1 -11.3 , 11.5 (pp. 687-692), 11.6
	I	Enumeration & Relaxations	1	Enumeration Limits and Relaxation Basics	12.1, 12.2
	J	LP Branch & Bound Search	1	Rudimentary LP-Based Branch and Bound	12.3
			2	Bounds and Termination	12.4
7 Feb 27- Mar 5	K	Cutting Planes and Branch and Cut	1	Valid inequalities / Cutting Planes	12.5 (pp 777-788)
			2	Branch and Cut	12.5 (rest), 12.6 (pp 787-788)
	L	Network Flow Modeling	2	Formulating flow, transportation and assignment models	10.1, 10.6
	M	Network Flow Algorithms & Integrality	1	Cycle direction search	10.2
			2	Network flow integrality	10.5
8 Mar 6-12	N	Shortest Paths & Dynamic Programming	1	Shortest path algorithms	9.1-9.3, 9.5
			2	Discrete dynamic programming	9.8
	O	Computational Complexity	1	Measuring algorithm/problem complexity	14.1-14.3
			2	P vs. NP theory of hard problems	14.4-14.6
	MIDTERM 2 (three hours arranged within Mar 6-12)				

Lesson Master Pages

There is a multi-part master page posted for each block of the course under the **Lessons** tab of the Blackboard material for the course.

- **Things You Should Be Able to Do** comprises the first part of the learning objectives for the block – the skills and problem-solving capabilities you should learn. These are the first step in realizing the course's goal of introducing students to modeling and analysis in optimization.
- **Principles You Should be Able to Apply and Justify** comprises the second part of the learning objectives for the block -- the key theoretical insights you should understand sufficiently to explain, apply and justify as part of studying the block. These add the second step of learning the rationales behind methods presented as a start on mastering related optimization theory.
- **Lecture Materials** for each module of the block include buttons to play the recorded lecture(s) for the module, along with reference material students will need to follow the lectures including "Screens" PowerPoints where available, and/or "Exhibits" to which the instructor refers during the lecture.

- **Assigned Readings** for each module of the block detail text (2nd edition) materials students should study to gain a full understanding of the module.

- **Homework Exercises** for each block assign tasks utilizing the "Things" skills part of learning objectives, and applying the "Principles" part. It is the instructor's strongly held belief from long experience in teaching this material that the only way for students to master math-heavy material like this course is to require them to work with it in exercises.

How to Study Blocks and Modules of the Course
It is recommended that students study each of the blocks and modules of the course in approximately this sequence

1. Skim through the assigned text/reference materials for the module to capture the main ideas and tools involved
2. Download, and print or save to a write-on electronic pad, the "Screens" or "Exhibits" material for the module so that they will be available for note-taking as the lecture is played
3. Play and watch the recorded lecture for the module, taking notes on or around the downloaded lecture materials
4. Do and submit solutions for the assigned homework exercises, reviewing as needed relevant parts of the text materials, or replaying parts of lectures
5. Return to the learning objective "Things" and "Principles" for the block before you move on. Take each in turn, be sure you have learned what is required, and make notes to help you study later for the exams. Often this will require you to again go back for more detailed reading of text materials, or replaying parts of lectures

Submitting Homeworks
Homework answers for each block of the course should be **submitted by email** to the instructor (rrardin@uark.edu) after scanning as electronic attachments and arranging in a single package. Homework papers should be **neat**, but there is **no requirement that they be typewritten**. Where **AMPL** software is required, **submit the final log file** for each model solved.

Students are **strongly** advised **not** to do their homework **casually or depend on published/pirated answers, notes, etc.** that may be available. Serious effort on the exercises **directly** prepares students for the "Things" part of the learning objectives, which **will be the source of a major part of exams**.

A **recommended** submission date is listed on the block master page for homework of each block. However, submissions will be accepted through the **last-chance** date, which is the Sunday ending the associated week of the course. Notice that this implies **more than one block may be due on the same last-chance day. No results will be accepted** after the last-chance date for the week

Homework submissions will be **lightly** reviewed for completeness and main ideas by the instructor, scored on the basis of 20-60 points per assignment, and emailed back to the student. Assignments will **not** count equally; total points are shown with each block. Shortly after the last-chance date/time for each block has passed, **solutions** will be available through **Blackboard** class software.

Examinations
Two **proctored Midterm examinations** occur at the ends of the two halves of the course, each **covering only material in that half**. Exam questions **will closely follow the Learning Objectives** for covered blocks, requiring students to execute algorithms, apply relevant theory, formulate simple applications, and justify underlying principles. **Copies of typical midterms from earlier offerings are available (without answers)** through **Blackboard** class software.

The first Midterm exam for each student will take place sometime **Fri-Sun, February 16-19** and the second sometime **Fri-Sun, March 9-12. Students are responsible** for recruiting appropriate proctors and submitting the request form downloadable from the course **Required Material** in Blackboard. Both exams will provide students up to **3 hours** to prepare their solutions under the watch of proctors in order to allow **balanced coverage of all the learning objectives** without excessive **time pressure**.

Both exams will be **almost closed book**, i.e., students may use **no** books/notes **except two 8 1/2" by 11" sheets** of **handwritten** notes (both sides). **Multi-function calculators, pads, laptops, and wireless/telephone communication devices are prohibited during exams.** Instead, students should arrange to bring a simple calculator without programmable or wireless communication features for use during exams. Proctors will be responsible for approving both the notes and the calculators used, and electronically scanning, then emailing student papers to the instructor at **rrardin@uark.edu**.

Partial Credit and Answer Explanations/Justifications
Most homework and exam questions involve answers for which it is appropriate to award partial credit if **answers include brief justifications**. To avoid confrontations, **partial credit scoring will never be discussed** one-on-one. In any case where the student believes scoring is inappropriate, he/she should attach a covering note briefly explaining why scoring seems wrong, and submit the subject item for a **regrade** by email within **one** week after papers are returned. The instructor will then reconsider the scoring in light of those written comments and determine what, if any adjustment is appropriate. He reserves the right to review all parts of the exam/homework if regrade of any part is sought.

Academic Honesty
Discussion of course content among students aids learning and is encouraged. However, each student is expected to submit his/her own work. No two submitted homework papers should ever be identical on any major part. No cooperation of any kind, or use of unauthorized notes and devices, is allowed during proctored examinations. A discussion of Academic Honesty policies, and processes is available at the University website http://honesty.uark.edu/policy/index.php .

Grading
Although the instructor reserves the right to deviate from strict mathematical weighting, grades will normally be derived as follows:

- After each exam is graded, the instructor will announce a (nonnegative) calibrating **boost** to be added to every student's score in final course grade weighting.
- Then adjusted grades will be weighted **40% for each exam**, and **20% for homework average** (unadjusted total points received divided by total points possible) to obtain **weighted averages.**
- Those students with a weighted average at least 90% are guaranteed an `A', 80% a `B', 70% a `C', and 60% a `D', etc.