OR 604: Practical Optimization George Mason University

Department of Systems Engineering and Operations Research

Spring 2016

Time: Tuesdays 7:20 PM to 10:00 PM
Classroom: 1108 Nguyen Engineering Building
Professor: Dr. Steven Charbonneau
Phone: (202) 418-4076 (work) from 08:30 AM to 5:30 PM
(703) 550-5006 (home) from 6:30 PM to 9:00 PM
Email: scharbo2@gmu.edu
Office hours: By Appointment only

Texts:

Optimization in Operations Research, Rardin, R.L., Prentice Hall, 1998.
Hello World, Sande, W and Sande, C, 2009, (ISBN 1933988495)

Course Description: This course builds on the techniques learned in Analytics and Decision Analysis (OR 531). As data of huge sizes becomes ubiquitous, analysts must learn to set up, formulate, solve, and interpret prescriptive models of unprecedented size. This course describes optimization techniques and codes capable of working in the Big Data setting. The course will use state-of-the-art optimization packages coupled with a programming language and databases suitable for big data analyses. The course covers model formulation, convexity, linear programming, integer programming, and heuristic methods. *You will be writing and running your own code for each homework assignment. Do not be confused, it is a very large part of this course. If you do not know how to write code, you will be provided the resources and adequate opportunity to learn through application and frustration. This means you will allocate more time to this course in the beginning of the semester than your peers. If you have concerns, start the tutorials that are in the course blackboard site before the course starts.*

Course Objectives: This course focuses on developing student skills in the formulation and implementation of large-scale optimization models. At the end of this course, students will be able to:

- Formulate large-scale optimization models by taking advantage of the regular structure of families of constraints
- Solve large-scale optimization models by employing advanced techniques and heuristics that allow generally intractable problems to solve
- Take advantage of the advanced features of commercial optimization engines
- Set up, read from, and write to databases using SQL statements run from a programming language

- Create and run routines in Python that can be used to formulate and solve optimization problems.

Course Schedule: The course schedule is subject to change as the course progresses. Modifications will be posted on blackboard.

Lecture	Date	Topic	Prep Work	Overarching Theme
Lesson 01	19 JAN, 2016	Course Overview: Python I: Working with Lists and Dictionaries Python and SQL	*Python for Informatics - Exploring Information:* Chapter 1, 2, 3, 4, 5, 8, 9, 14 *Python for Scientific Computing:* Pages 1 – 63 *Text:* Chapter 1, 2	*Get your stack on!*
Lesson 02	26 JAN, 2016	Python II: Beautiful Soup Google Maps Linear Programming I: Overview of Linear Programming	Getting Started with Beautiful Soup: Chapters 2, 3, and 4 *Text Reading:* Chapter 4	
Lesson 03	02 FEB, 2016	Linear Programming II Transportation Problems Introduction to Gurobi and Python	*Text Reading:* Chapter 10; Sections 1, 5, and 6 *Papers:* • Summation Notation Doc 1 • Summation Notation Doc 2 • Converting your paper models to Python/Gurobi models • Pizza Case Study	*Pizza*

Lesson 04	09 FEB, 2016	Linear Programming III Integer programming The facility location problem	*Text: Chapter 11; Sections 1, 3, 6* Papers: Introduction to Integer Programming A Capacitated Facility Location Problem with Constrained Backlogging Probabilities (abstract, sections 1 and 2 only)	
Lesson 05	16 FEB, 2016	Heuristic approaches to hard problems I The Bin Packing Problem	Papers: Three Dimensional Bin Packing Problem with Variable Bin Height (Sections 1, 2, and 3 only) Multistage Cutting Stock Problems of Two and More Dimensions A New Heuristic Algorithm for Rectangle Packing	
Lesson 06	23 FEB, 2016	Heuristic approaches to hard problems II: The vehicle routing problem	*Text:* Chapter 11; Section 5 Chapter 12; Section 8 Papers: A Tutorial on Column Generation and Branch and Price for Vehicle Routing Problems (read to understand pages 1-3, scan the rest of the paper)	

			A Sweep Algorithm for the Mix Fleet Vehicle Routing Problem	
Lesson 07	01 MAR, 2016	Pizza Case Study: Pulling it all together	No new readings	
Spring Break				
Lesson 08	15 MAR, 2016	Linear Programming IV: Assignment Problems	Text: Chapter 11; Section 4 Paper: Sports Scheduling: Algorithms and Applications Consolidated rules for creating an NFL schedule	*Football*
Lesson 09	22 MAR, 2016	***Lab Time***		
Lesson 10	29 MAR, 2016	Linear Programming V: Soft Constraints with and without penalties	Paper: Hard and Soft Constraints in Linear Programming	
Lesson 11	5 APR, 2016	Linear Programming VI: Solving LP's with Multiple Objectives	Text: Chapter 8	
Lesson 12	12 APR, 2016	Heuristic Approaches to hard problems III: Trading quality for speed	Readings TBD	

Lesson 13	19 APR, 2016	Heuristic Approaches to hard problems IV Fixing what we broke in the previous lesson	Readings TBD	
Lesson 14	26 APR, 2016	Football Case Study: Pulling it all together *	No new readings	
Final Exam	**3 May, 2016**	***May or may not happen. Ask about it in class when we start the Football problem. Depends on whether Lesson 14 gets pre-empted by a better topic***		

** May be pre-empted by a far better topic*

Grading Scheme:

Homework: 90%

Class participation: 10%

Coursework & Grading: Unless otherwise indicated, you are expected to work individually on homework assignments. You must submit homework directly to me via email at scharbo2@gmu.edu.

Academic Integrity: GMU is an honor code university; please see the University Catalog for a full description of the code and the honor committee process. The principle of academic integrity is taken very seriously and violations are treated gravely. What does academic integrity mean in this course? Essentially this: when you are responsible for a task, you will perform that task on your own. When you rely on someone else's work in an aspect of the performance of that task, you will give full credit, in writing, as a cover document to your homework submission. Another aspect of academic integrity is the free play of ideas. Vigorous discussion and debate are encouraged in this course, with the firm expectation that all aspects of the class will be conducted with civility and respect for differing ideas, perspectives, and traditions. When in doubt (of any kind) please ask for guidance and clarification.

GMU Email Accounts: Students must use their Mason email accounts to receive important University information, including messages related to this class. See http://masonlive.gmu.edu for more information.

Additional Notes:
I will make every effort to use Blackboard to post homework, assignments, lecture notes, and grades. I will send out email notices each time I have uploaded new information to blackboard.

Failure to turn in homework on the due date will result in a 0% for that submission.

Best way to contact the professor is by email.

The following is a great source for getting started on Python and SQL: The GMU library has an academic subscription to Safari Books Online; a repository of technical books on programming, big data, math, and all sorts of IT subjects. These are books (from publishers like Wrox, Sams, and O'Reilly) you generally would spend between $50 and $150 if you wanted to buy your own copy. As an academic license, it is limited in its features (cannot bookmark or highlight pages) but it is an excellent resource. Get to it from the following URL and use your GMU credentials to log on:
https://login.gmu.edu/login?service=https%3a%2f%2flogin.mutex.gmu.edu%2flogin%3fqurl%3dezp.2aHR0cDovL3Byb3F1ZXN0LnNhZmFyaWJvb2tzb25saW5lLmNvbS8.dWljb2RlPXZpdmE-

Hardware:
You will need to bring a laptop to class each lesson. If you have both a Mac and a PC, I encourage you to bring the PC. If you were looking for a reason to buy a new laptop and you think this course is your reason – good on you. I strongly encourage you to get a PC based laptop running Windows with an Intel processor (as opposed to AMD).

1. *Why Intel:* For some reason, Intel processors are better designed for math intensive operations whereas AMD has its strengths in other areas (*I have no idea what that would be*). Case in point, two former students bought brand new AMD laptops with four cores, 3.5+ GHz speed, with 4 to 8 GB RAM specifically for this course. Their laptops could not get a feasible solution in less than 10 hours. Running their models on my 5 year old Intel i3 duo core laptop with 4 GB RAM and 2.1 GHz speed, I could get a feasible solution in about 10 minutes. Your call on how you want to spend your time.
2. *Why Windows:* If you have a Windows laptop your life will be much easier (*in this course at least*) than if you try to use a Mac laptop. I didn't write the Gurobi software, I'm just telling you the cold hard facts. For you Windows haters out there, sometimes you just have to acknowledge that Mac doesn't always mean easier. If you insist on using a Mac, once (if) you get your environment up and running, you should be okay. The latest release of Gurobi may have fixed this situation. At the end of the semester you Mac users can tell me if this is still a valid statement. If you have a Chrome book running Linux, good luck. You are on your own. I have no idea if it even works.

Software:

You will need to download and configure software for this course. Before downloading and installing all of the software listed in this syllabus, scan the **Gurobi Quick Start Guide** to figure out the order and sequence of software to be loaded. If you do not reference the quick start guide for your OS, you will undoubtedly run into issues. Please read it first.

NOTE: If you are using Windows 8.0 or higher as your OS, you MUST use the 64 bit versions of the software. You don't get a choice. Well, actually you do, but it won't work.

Gurobi – We will use Gurobi as our optimization library. I recommend you use the latest version of Gurobi (currently 6.5). If you have some other version loaded, it will be well worth it to upgrade your license to 6.5. There is no reason not to upgrade since it is free for academic users (you are an academic user if you are taking this course). You will need to register on the Gurobi website to download the software. Go to www.gurobi.com to register and download your academic license.

Before you can use Gurobi, the software must validate your academic standing. It does so by checking your IP address and ensuring it is a legitimate academic domain. Once validated, your license is good for a year. You can validate your license in one of two ways:

1) *Easy but inconvenient:* Go to the GMU campus, log onto the network as a student, and then follow the directions in the Gurobi Quick Start Guide for validating Gurobi.
2) *Convenient but potentially frustrating:*
    a. Download and install OpenVPN (http://labs.vse.gmu.edu/index.php/Services/VPN),
    b. Download and install Cisco AnyConnect for your computer operating system (http://itservices.gmu.edu/downloads/index.cfm#CP_JUMP_34249),
    c. Start OpenVPN as an Administrator (the connect window will be green). Opening as an administrator is important.
    d. Start Cisco AnyConnect (the connect window will turn yellow, wait a few seconds it will turn green)
    e. Once the connection window has turned green, open an internet browser to any page to confirm your connection is valid
    f. Follow the instructions in the **Gurobi Quick Start Guide** for academic validation.

Python –Gurobi supports the Anaconda distribution of Python 2.7. This statement is true for both Windows and OSX. I strongly encourage you to use this distribution. It will work with other IDE's, but it will not be guaranteed to work. Go to Continuum Analytics download page (https://www.continuum.io/downloads) to get the correct version of Python (did I mention you want 2.7?)

SQLite Studio – This is an optional piece of software. If you are inexperienced with Structured Query Language (SQL) you may find this a useful tool. It is a graphical user interface and database management tool for SQLite (the database library that ships with Python). By using this software you will be able to test your SQL commands and statements before you run them in your Python routines. To download a copy of SQLite Studio go to http://sqlitestudio.pl