IE 8753: Network Flows and Dynamic Programming

Hugh Medal

Syllabus, Fall 2014

Course Information

Instructor

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Office Hours

My office hours for this class will be: **10:30-11:30am Mondays and Wednesdays**.

I will try notify you if I am ever not available during this time. You are welcome to drop in. However, if you wish to reduce/eliminate waiting time, I would encourage you to schedule an appointment via https://hughmedal.youcanbook.me/. If you need to meet with me another time, please let me now. Distance students may wish to communicate with me using Skype, phone, or some other method. I will not be available on Tuesdays or Thursdays unless there is an urgent need.

Course materials

Required textbook *Network Flows*, Ravindra K. Ahuja, Thomas L. Magnanti, James B. Orlin, Upper Saddle River, NJ: Prentice Hall, 1993. The Solution Manual for this book is available on-line at: http://web.mit.edu/jorlin/www/SolutionManual/SolutionManual.html.

Other materials We will have a small number of handouts throughout the semester.

Prerequisites

A student should have training in linear programming (e.g., IE 4733: Linear Programming I). It is also important that you are competent in a general purpose computer programming language (e.g., Java, C/C++, Python, Matlab/Mathematica, etc.). You will use this language to implement the algorithms we learn in class. In addition, you should be able to use a linear programming solver (e.g., Gurobi, CPLEX, GLPK, etc.). We will use the solver to solve linear programs of various network optimization problems. There are two ways to use such a solver: 1) call the solver from a general purpose language (e.g., Gurobi has a Python API) or call the solver from a modeling language (e.g., AMPL, GAMS, OPL, etc.)

Course Description

An introduction to network flows optimization, focusing on three classes of problems: shortest path problems, maximum flow problems, and minimum cost flow problems. The class will emphasize modeling and algorithms, introducing theory as needed.

Expectations

I have arranged the schedule so that you only have assignments due on Mondays, and there is no more than one assignment due on a Mondays I expect that you will need to spend 5-10 hours per week doing homework, working on projects, and studying for exams. I will try to make the workload as regular as possible.

Assessment

Prerequisite Exam

During the first few weeks of the course, students will be given an exam testing their basic knowledge of course prerequisites (linear programming and computer programming).

Details

Collaboration None.

Submission format and method This exam will be take-home. Distance students will not need a proctor.

Due You must take this exam by the date listed on the course schedule.

Grading method This exam will not count towards your final grade. However, before you can submit HW1 you will need to make a 70% on the prerequisite exam. You will have three tries to do so (exam dates: 9/1, 9/8, and 9/15).

Problem Sets

Four problem sets will be assigned throughout the semester. The goal of the problem sets is to give you practice on what you learned in class and prepare you for the exams. My goal is for each problem set to take you 5-10 hours, depending on how well you grasp the material.

Details

Collaboration You may work in groups of 2 to 3. You must document any help that you received for the assignment; this includes materials and consultation with other individuals.

Submission format and method Your homework may be typed or handwritten. Handwritten homeworks must be *very* neat.

Due See schedule.

Grading method I will grade problem sets according to a rubric that will be provided with the problem set.

Exams

Students will given four exams, one for each part of the class. Here is an example of questions I might ask:

- Define the minimum cost network flow problem.
- Write pseudocode for solving the maximum flow problem using the capacity scaling algorithm.
- State and prove the complexity of Dijkstra's algorithm.
- Solve a shortest path problem by hand using Dijkstra's algorithm.

Time will be limited on this exam, so it will be important for you to be able to recite algorithms and theorems quickly. Thus, you should study them well enough so that you are able to recite them without much pause. Thus, each exam will include a small amount of material.

Details

Collaboration None. No outside materials will be allowed, including a cheat-sheet or textbook.

Submission format and method You will be given 55 minutes to complete the exam. If off-campus, please follow the normal process for taking exams (i.e.., use a proctor).

Due You must take this exam by the date listed on the course schedule.

Grading method The exams will be graded using a rubric provided before the exam.

Project

Students will complete a project over the course of the semester. This project will consist of applying techniques we learn in class to a network flow optimization problem. You will have the choice of a research project or a teaching and service project.

If you choose the **research project**, you will be expected to take a first step at making a contribution to the literature on applied or theoretical network optimization. You may wish to choose a problem from your dissertation research. Ideally, your project in this course will be the start of a journal article or conference paper.

For the **teaching and service project**, students are also expected to apply the skills they learn in class to a real-world problem with a real stakeholder, starting from defining the problem and culminating in an implemented solution. Students may choose any stakeholder they choose. Ideally students would work with a local company or, in the case of distance learning students, do a project for the company they work for. The emphasis on this project will be your ability to provide a solution that addresses real needs. The best projects will actually implement their solutions and discuss the results. In addition, this project will involve developing a teaching plan and materials for teaching a particular network optimization topic to a layperson.

Details

Collaboration Individual or groups of 2 to 3. If you work in a group, you should clearly state what each of you did in a separate document. I would like you have equal participation. The quality of work should increase with the size of your group.

Submission format and method

- **Proposal.** The proposal will not be graded. It is meant to help you. However, your proposal must be approved at least two weeks prior to submitting the progress report.
  - **Research project:** You should describe the problem you intend to work on as well as a brief literature review.
  - **Teaching and service project:** You should describe the problem you intend to work on as well as your stakeholder.
- **Progress report.** The progress report will not be graded. It is meant to help you. However, your proposal must be approved at least two weeks prior to submitting the final deliverables.
  - **Research project:** You should describe your problem in detail as well as the solution method(s) you plan to use.
  - **Teaching and service project:** You should describe the data you have collected as well as your proposed solution method.

- **Final deliverables.**
  - **Research project:** Your final submission will consist of a written report in the style of a journal article or conference paper. You should include a description of your solution method, validation of your solution method, and some preliminary experimentation.
  - **Teaching and service project:** Your final submission will consist of 1) a written report documenting your service project, 2) a teaching plan and materials.

Due

- **Progress reports.** See schedule for syllabus.
- **Final product.** See schedule for syllabus.

Grading method

- **Progress reports.** Your progress will be graded using a rubric provided with the assignment.
- **Final product.** Your final report will be graded by the instructor using a rubric provided with the assignment.

Extra Credit

Reading Memos

There will be approximately 13 reading memos assigned over the course of the semester. Each reading will take about 1 hour, on average, and will be sufficient preparation for class. The reading memo will consist of one or more reading passages. For each part, I recommend that you do the following:[1]

Passage from Textbook

1. **Outline.** Scan through the text. Write an outline of the section headings.
2. **Summary.** Read the introduction and conclusion. Write a quick summary (1–3 sentences) based only on the introduction and conclusion.
3. **Read.** Read the part straight through. As you read make notes of things you don't understand, things you do understand, things you think are important, things you think are unclear, questions you have, etc. Include these notes (in raw form) in your reading memo.
4. **Review the difficult parts.** Go back and try to understand the things that you had difficultly with during your first read. Sometimes things make sense after reading the entire part or just after spending a little more time. Write down the things that you understood after looking at it a second time. Also write down what is confusing to you.

Passage from a Journal Article

1. **Outline.** See above
2. **Summary.** See above
3. **Read.** Read the passages in the article listed in the assignment. Pay attention to the things listed in the assignment. You don't need to read the entire article unless I ask you to. Again, as you read you should make notes (see above) and include them in your reading memo.
4. **Review the difficult parts.** See above.

[1] This is a particular process for reading that I think works well. If you feel that you learn better through a different process of reading, please let me know. I am open to allowing you do what works best for you.

Details

Collaboration This can be an individual or in groups of 2 to 3. If you do your assignment in a group, you should include a 5th step titled "Group Discussion". During this step you should discuss your answers from #4 amongst your group. Write down which things you resolved after a group discussion. Also write down which things you still have trouble with. If you work in a group, you must include a Steps 1–4 for each person and for each passage. Do Step 5 as an entire group for each passage.

Submission format and method Please submit your reading memos to me in an email. The subject of your email should be "Reading memo Y: LastName(s) (YY/MM/DD), where Y is the number of the reading memo and YY/MM/DD is the due date. Please put your names in alphabetical order. For ease of grading, if you work in a group, please work together on all of the passages that you attempt.

Due At 8am on the Monday of the week that we start the reading. For example, the reading memo for Chapter 3 will be due at 8am on August 25th.

Grading method The grade will be based on effort. Each reading passage will be worth 4 points. If you do not do it or do a very poor job, you will get 0% (0 points). If you do the reading memo but leave material out or do a poor job, you will get 50% (2 point). If you a satisfactory job on the complete assignment, you will get 100% (4 points). Group submissions will receive a bonus of 25%, and each group member will get the same grade.

Article Review

Part of the job of a scholar is to review the work of others and provide feedback. For this class students will critically read a potential journal article and comment on its strengths and weaknesses, ultimately making a decision of whether the article is suitable for submission.

Details

Collaboration This is an individual assignment.

Submission format and method The student will submit a typed referee report. Guidelines will be given later in the semester.

Due 11/3 at 8am.

Grading method Your referee report will be graded using a rubric provided with the assignment. You will be given up to 25 points of extra credit.

Grading

Grade Distribution

Your final grade will be based on the proportion of points that you earn on reading memos, exams, review exam, and the final project.

Type	Points Each	Quantity	Total Points	Percentage
Problem sets	50	3	150	21.4%
Exams	100	3	300	42.8%
Project	250	1	250	35.7%
SUM		7	700	100%

Grading Scale

The following scale represents the minimum percentages needed for you to be guaranteed each letter grade.

A	90%
B	80%
C	70%
D	60%
F	50%

However, I also use gray areas to determine grades. The gray areas are as follows:

A	89-90%
B	78-80%
C	67-70%
D	55-60%

If you in a gray area, your grade may be bumped up based on the following criteria: Did you give attempt any of the challenge problems on the problem sets? Did your grade increase over the course of the semester? If you are not in a gray area, please do not ask for your grade to be bumped up.

Guidelines and Policies

Exam Proctoring for Distance Students

Distance students must exams using a proctor approved by the instructor. Arrangements, including the proctor approval sheet and the date and time that you will take the exam, must be submitted one week before the exam is scheduled. The proctor approval sheet only needs to be submitted once for each proctor you use. You may take the exam within the time window starting at 8am one business day before the exam and ending at 5pm one business day after the exam. Exceptions to this rule will be granted for special cases. However, I expect you to make arrangements as soon as you can. The proctor should email a scanned version of your exam and mail the original.

Academic Honesty

We will comply with the MSU Honor Code (http://www.honorcode.msstate.edu/pdf/honor-code.pdf), which requires me to report cases of academic dishonesty (page 8). Examples of academic dishonesty include by are not limited to the following:

- Using unauthorized materials/resources on an exam
- A conversation about an exam between a student who has taken the exam and a student who has not yet taken it
- Collaborating with other individuals (whether they are students in our class or not) on any assignment that does not allow collaboration
- Not documenting any resources you used on an assignment
- Plagarism: using the work of others without proper citation

Students Needing Extra Accommodation

If there are any issues that may affect your learning, please let me know. I would like to make accommodations in any way I can. In addition, you may wish to consult with Student Support Services (http://www.sss.msstate.edu/disabilities/).

Course Schedule

Notice that the schedule was designed so that all exams are on Mondays and all deliverables are due at 8am on Mondays.[2] However, the schedule is designed to allow you enough time to complete your assignments by Friday.

This schedule was also designed to be regular. Thus, I do not plan on extending any due dates except as a last resort, to avoid having multiple assignments close together. However, I am willing to reduce the scope of an assignment if I discover that it is too much work for 1 week. Therefore, I would like you to begin working on your assignments well in advance of the due date so that you are able to give me feedback.

		Part	Topics	Assignment/Exam	Read
Aug	18—22	1: Intro	Terminology and notation	None	Ch. 1 (due 8/20) Ch. 2 (due 8/22)
	25—29		Algorithm design and analysis	Prerequisite take-home exam: due 9/1 at 8am	Ch. 3
Sep	1		Holiday: Labor Day		
	3		Algorithm design and analysis	None	Ch. 3
	8—12	2: Shortest path	Introduction	None	Ch. 4
	15—19		Label-setting algorithms	None	Ch. 4
	22—26		Dijkstra's algorithm Label-correcting algorithms	None	Ch. 4
	29—3 Oct		Label-correcting algorithms All-pairs shortest paths	None	Ch. 5
Oct	6—10	3: Max Flow	Basic ideas	HW 1: due 10/6 at 8am	Ch. 6
	13—17		Basic ideas	**Exam 1: 10/13**	Ch. 6
	20—22		Basic ideas Polynomial algorithms	None	Ch. 7
	23—24		Holiday: Fall Break		
	27—31		Polynomial algorithms	None	Ch. 7
Nov	3—7		Polynomial algorithms	None	Ch. 7
	10		No class	HW 2: due 11/10 at 8am	None
	14		**Exam 2: 11/14 at 9am (distance students have from 11/10 to 11/16)**		
	17—21	4: Min. cost flow	Basic algorithms		Ch. 9
	24		Basic algorithms		Ch. 10
	26—28		Holiday: Thanksgiving		
Dec	1		Polynomial algorithms	HW 3: due 12/1 at 8am	Ch. 10
	8		**Exam 3: 8am on 12/8 (75 minute exam)**		
	12		Project: due 12/12 at 8am		

A Recommended Resources

- High-level programming languages
  - Python (https://www.python.org/) with NetworkX package (https://networkx.github.io/) and/or GiMPy (https://pypi.python.org/pypi/coinor.gimpy/1.3.2)

[2] All times are Central Time unless otherwise noted.

  - MatLab

- Optimization solvers and modeling languages[3]
  - Gurobi solver (http://www.gurobi.com/) using Python interface
  - Gurobi using the modeling language AMPL (http://ampl.com/)
  - CPLEX solver (http://www-01.ibm.com/software/commerce/optimization/cplex-optimizer/) using AMPL

- Books
  - Linear Programming and Network Flows (Bazarra, Jarvis, Sherali)

- Lectures notes
  - http://people.orie.cornell.edu/dpw/techreports/cornell-flow.pdf
  - http://coral.ie.lehigh.edu/~ted/teaching/ie411/

[3]Both Gurobi and CPLEX have free academic licenses.