IE801(31.801)B Special Topics in Industrial Engineering II <Logistics Systems Optimization>

Spring 2024 Syllabus (subject to change)

Course Contact

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- Office Hours: To be determined

Course Description

This course covers selected topics in mathematical models for logistics network modeling, design, and optimization. We will briefly review basic topics in network optimization and then will proceed to commonly used models for logistics service planning by private companies as well as management of public network infrastructure, with emphasis on transportation systems. This course will cover topics such as the traveling salesman problem, vehicle routing problems, network design, and location problems. This course will introduce large-scale optimization algorithms such as Branch-and-Price, Branch-and-Cut, Branch-Cut-and-Price, Lagrangian Relaxation, Benders Decomposition, and Cutting Planes in the context of transportation and logistics systems.

Prerequisites

- Knowledge of a computer programming language such as C, C++, Java, Python, MATLAB, and Julia. This course will particularly emphasize the Julia Language.
- A course in linear optimization.

Optimization Software

This course involves homework assignments that require optimization software. In particular, the students will learn how to use The Julia Language with the Gurobi Optimizer. Students are encouraged to install Julia and Gurobi on their own computers. Students shall access the following web document for installation help and example codes: https://www.chkwon.net/julia/. More information will be provided.

Grading

- ABC Letter Grade
- **10% Class Attendance and Participation.**
- **40% Homework Assignments.** Students must work on the homework problems independently. Students are allowed to discuss with other students, but each student must present the idea independently. The allowed discussion does NOT include reading other students' writings and codes.

    - For all coding assignments, you are okay to use Python, MATLAB, R, or any other languages. If you use Julia or Java, however, you get 10% bonus points. If you use C or C++, you get 15 % bonus points.
- **25% Project Proposal/Progress Evaluation.**
- **25% Project Final Presentation/Report Evaluation**

Project

The project is a major learning outcome of this course. Each student independently picks an algorithmic paper in the field of network optimization and implements the algorithm therein to replicate the experimental results in the paper. To pick a paper, students are encouraged to survey papers in journals like *Operations Research, Transportation Science, Transportation Research Part B: Methodological, European Journal of Operational Research, INFORMS Journal of Computing, Networks, Computers & Operations Research,* and other similar journals. The algorithm of choice can be exact or heuristic, and the problem can be classical or modern. Students should start seeking a paper early in the course and are encouraged to consult with the instructor when they have doubts.

If students are interested in developing new computational methods for important problems, they should consult with the instructor before they submit their proposal.

Important Dates:

- **(Proposal) Week 5 / Monday: Initial pick of paper submission.** Students need to submit a short description (no more than 1 page) for the paper of their choice, with a plan to implement the algorithm using a computer language (no more than 1 page). This plan can include:
    - the choice of computer language
    - the target experiment results to replicate
    - the part that the students will implement by themselves and the part that external libraries will be used
    - expected timelines and milestones

For some papers, authors could have posted their own computer codes on github.com. In such cases, students are encouraged to read their codes but need to write their own codes, preferably in another computer language.

(Revised Proposal) Week 6 / Monday: Revised pick of paper submission. The instructor will give students feedback on the choice of paper and discuss it with the student. If necessary, a revised plan should be submitted.

- **(Progress Report) Week 7 / Monday: 10-minute presentation on the progress.** Each student will report on the current progress. Introduce the basic nature of the problem and the algorithm. Report any achievement and difficulty.
- **(Final Report) Week 16 / Monday: 20-minute final presentation.** Each student will share what they achieved and what they learned.

Course Schedule and Topics Covered (subject to change)

<table>
<tr><th>Week</th><th>Topics</th></tr>
<tr><td>1</td><td>Introduction to Vehicle Routing and Location Problems
Review of Linear Optimization and the Simplex Method</td></tr>
<tr><td>2</td><td>The shortest path problem
Network flow problem
The transportation problem
Multi-commodity network flow problem
Dijkstra's algorithm
Label-correcting algorithm
Traveling Salesman Problem
Subtour Elimination
Vehicle Routing Problem (VRP)
VRP with Time Windows
Capacitated VRP</td></tr>
<tr><td>3</td><td>Green VRP
Bike Rebalancing
Branch and Bound for Binary Integer Programming
Lazy Constraints for TSP
Callback in Gurobi
Concorde
Route Construction Methods for TSP
Nearest Neighbor
Greedy Algorithm
Nearest Insertion
Farthest Insertion
Double MST
Christofides</td></tr>
<tr><td>4</td><td>Route Improvement Methods for TSP
2-opt Exchange
3-opt Exchange
Lin-Kernighan
LKH, elkai
Metaheuristics
Genetic Algorithm
Simulated Annealing
Dynamic Programming for TSP
Neural Combinatorial Optimization</td></tr>
<tr><td>5</td><td>Branch and Cut for TSP
Cutting Plane Algorithm
Comb Inequalities
Branch and Cut for VRP</td></tr>
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	• Rounded Capacity Inequalities
6	• Column Generation for the Shortest Path Problem with Resource Constraints • Column Generation for Vehicle Routing Problems with Time Windows
7	**Project Discussion**
8	• Branch and Price for VRPTW: elementary vs. nonelementary • Labeling algorithm for Elementary Shortest Path Problem with Resource Constraints • Branch-and-Cut-and-Price for CVRP
9	• A clustering approach for VRP • Hybrid Genetic Algorithm • Adaptive Large Neighborhood Search • VRP Software and Data

10	• Random number generation
	• Benders Decomposition for Two-Stage Fixed-Charge Location Problem
	• Review of Decomposition Principles
	  ○ Dantzig-Wolfe Decomposition (Column Generation)
	  ○ Benders Decomposition (Row Generation)

11	**Project Progress Presentation**
12	• Classic Location Problems • Hub Location Problems • EV Charging Station Location Problems
13	• Lagrangian Relaxation for MILP • Lagrangian Relaxation for p-Median

14	• Network Design
	  ○ Discrete Network Design Problem
	  ○ Continuous Network Design Problem
	  ○ A Basic Formulation
	  ○ Benders Decomposition
	• Stackelberg Game
	• Bilevel Optimization
	• Single-Level Reformulation
	• Network Interdiction Problem

15	• Network Interdiction Problem • Pessimistic Bilevel Optimization
16	**Project Final Presentation**