# MATH 441 Discrete Optimization Problems

*Group Project Outline 2022W1*

## Group Formation

- 3 or 4 students per group
- Combined skill set should include Python/MATLAB/Julia and LaTeX
- Each group must select a project distinct from other groups
- Submit project description, names and student numbers of group members
- Deadline: Friday September 23

## Project Proposal

- Clearly state the problem to be solved or question(s) to be answered
- List relevant references and examples
- Identify data to collect and computations to perform
- Submit LaTeX document (at most 1 page)
- Deadline: Friday October 7

## Progress Report

- Clearly state the problem to be solved or question(s) to be answered
- Give a summary of the big ideas and work completed to date
- Give examples of data collected and computations performed
- Submit LaTeX document (at most 3 pages)
- Short group presentation in class (at most 5 minutes)
- Deadline: Tuesday November 8

## Final Report

- Problem statement
- Relevant mathematical theory
- Data and computations
- Presentation of results
- Submit LaTeX document and Python/MATLAB/Julia code
- Deadline: Friday December 2

# Group Presentation

- Summarize the big ideas and results
- 10 minutes plus 5 minutes for questions and discussions
- Deadline: Tuesday December 6

# Grading Rubric

The final report will be graded according to 3 criteria: *Presentation*, *Clarity* and *Creativity & Understanding*. Each criteria is evaluated on a scale from 1 to 5:

| 5 | *Excellent* | Each item in the criteria is clearly satisfied. |
|---|---|---|
| 4 | *Very Good* | Almost all items in the criteria are satisfied. Some minor improvements required. |
| 3 | *Satisfactory* | Most items in the criteria are satisfied. Several minor improvements required. |
| 2 | *Developing* | Most items in the criteria are not satisfied. Some major improvements required. |
| 1 | *Needs Revision* | Almost all items in the criteria are not satisfied. Several major improvements required. |

### Presentation (5 marks)

- Precise mathematical notation
- Computer code formatted according to style guide[1]
- Correct spelling and grammar throughout
- Headings, links and text properly formatted
- Figures presented clearly with title, captions, labels, legend, etc.
- All references properly cited (see UBC Library's How to Cite Guide)

### Clarity (5 marks)

- Excellent writing with clear explanations
- Includes appropriate level of detail for audience (MATH 441 students)
- Precise mathematical statements throughout
- Well-organized and easy to follow

### Creativity & Understanding (5 marks)

- Demonstrates mathematical maturity far beyond basic definitions
- Well-constructed mathematical arguments throughout
- Makes nontrivial connections between disparate concepts
- Restates familiar mathematical concepts in a novel way
- Presents complex mathematical information in a simple way

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[1]See Python style guides PEP 8 and PEP 20, MATLAB Programming Style Guide Wiki and Julia Style Guide

# Project Ideas

## Create Your Own

Please let me know (pwalls@math.ubc.ca) as soon as possible if you plan to create your own project. We will need to make sure it not too difficult or too easy to complete. The best way to think of your own project is simply to pick a topic that you are interested in and then think of a quantity to optimize! For example:

- Design an asset mix in a financial portfolio to maximize return and minimize risk.

- How does a computer allocate CPUs/memory to maximize speed and minimize energy usage?

- Design a bridge to maximize strength and minimize weight.

Or feel free to modify any of the suggestions below!

## Streaming Service

Collect data about which TV series people like to watch, how much each series costs to gain rights to stream and find a selection of series which maximizes the number of subscriptions.

## Organize a World Tour

Choose your favourite music group. Find 10-20 cities on each continent where the group is popular and estimate the size of venue they can fill in each city. Determine the cost of staging the concerts, the revenue from ticket sales and the travel costs between cities. Determine the list of cities and the route that will maximize the profit of a world tour.

## High Performance Software for Linear Optimization

The function `scipy.optimize.linprog` for solving linear optimization problems is built on high performance software called HiGHS. The mathematical framework of HiGHS is explained in the paper *Parallelizing the dual revised simplex method* by Q. Huangfu and J. Hall. How does HiGHS work? What algorithms does it implement? How much faster is HiGHS than just the regular simplex algorithm?

## BC Hydro Power Transmission

British Columbia produces most of its electricity from hydroelectricity. There are many generating stations across BC which deliver power to residents through 75,000km of transmission lines. How much does it cost to move electricity over the transmission lines? What is the best way to distribute power across the province to meet demand while minimizing costs?

## Sports Team Management

Choose your favourite sports league, collect player data and design a team that optimizes performance. For example, design an NBA team which consists of at most 20 players with 10 forwards and 10 guards and with total salary below the salary cap which maximizes a combination of offensive and defensive efficiency.

## Evo Car Share Distribution

Evo is a car share program in Vancouver. The distribution of cars across the city becomes uneven as users drive and park cars in different locations. If Evo hires drivers to redistribute cars, what route should the drivers take to minimize the cost of redistributing the cars?

## Sports Scheduling

Choose your favourite sports league and design a game schedule which satisfies the many constraints particular to the league. For example, in the NBA, teams play the other teams in their division 4 times each and they play teams in the other conference twice, and the number of games played at home should be the same as the number of away games. Identify all the constraints, determine revenues for each game, determine the travel costs and maximize the profit.

## Starbucks Deliveries

Starbucks needs to deliver supplies to over 50 locations in Vancouver. Determine an optimal delivery strategy using 5 delivery trucks by either minimizing total mileage or minimizing delivery time.

## UBC Exam Scheduling

Given a dataset of (anonymous) UBC students and the courses they are registered in, determine an exam schedule without conflicts which uses uses as few days as possible such that students write at most 3 exams over 2 days.

## IKEA Delivery Planning

IKEA sells many items of different weights and sizes and the company needs to ship these items to their stores. How should the company pack the items into shipping containers to use the fewest containers?

## Compressed Sensing in Medical Imaging

There are health and financial costs when gathering measurements for medical imaging and compressed sensing reduces the measurements required to reconstruct an accurate image. What are the most common types of medical imaging and what are the costs? How many measurements are required to produce an accurate image by compressed sensing? Find simple examples of medical imaging data and compute the reconstruction by L1 optimization.

## Recommender System for Vancouver Restaurants

Create a recommender system for Vancouver restaurants based on collaborative filtering. Collect user ratings for restaurants and compute the matrix completion for the data matrix to predict user ratings for new restaurants.

## Single Pixel Camera

Digital photography relies on a process where the camera captures as much data as possible (20 megapixels in the Canon PowerShot ELPH 360 HS for example) and then the image is compressed into a format such as JPEG. The result is that much of the data collected is discarded. Compressed

sensing allows a camera to collect incomplete image data and then construct an approximation of the image by L1 optimization so that only necessary data is collected. The most extreme version of this process is the single pixel camera (SPC). How does a SPC work? How many measurements does the SPC require to reconstruct an image? Implement a simple version of a SPC by reconstructing small images with L1 optimization.