CMSC 150 — Final Project

Numerical and Symbolic Computation — *Specifications*

Project Context

The goal of this project is to create an application that will implement the **Simplex Method** to optimize (minimize or maximize) an objective function provided with necessary constraints. A specific feature will be the River Quality Cost Projector. The specific objective for this feature is to **find the cheapest cost** in cleaning portions of the Marilao-Meycauayan-Obando River System (MMORS) in Bulacan, which is currently infested with heavy metals. This is assumed that each heavy metal is to be treated individually at the parts of the river.

Water and sediment samples are being collected in river monitoring stations scattered throughout the MMORS. These are then being processed by biotechnological institutions such as the UPLB Biotech to collect the data of these river quality components. Each river monitoring station holds a probe which is good for a certain water volume. The figure below shows an example of the placement of the river monitoring stations, each with a corresponding GPS tag.

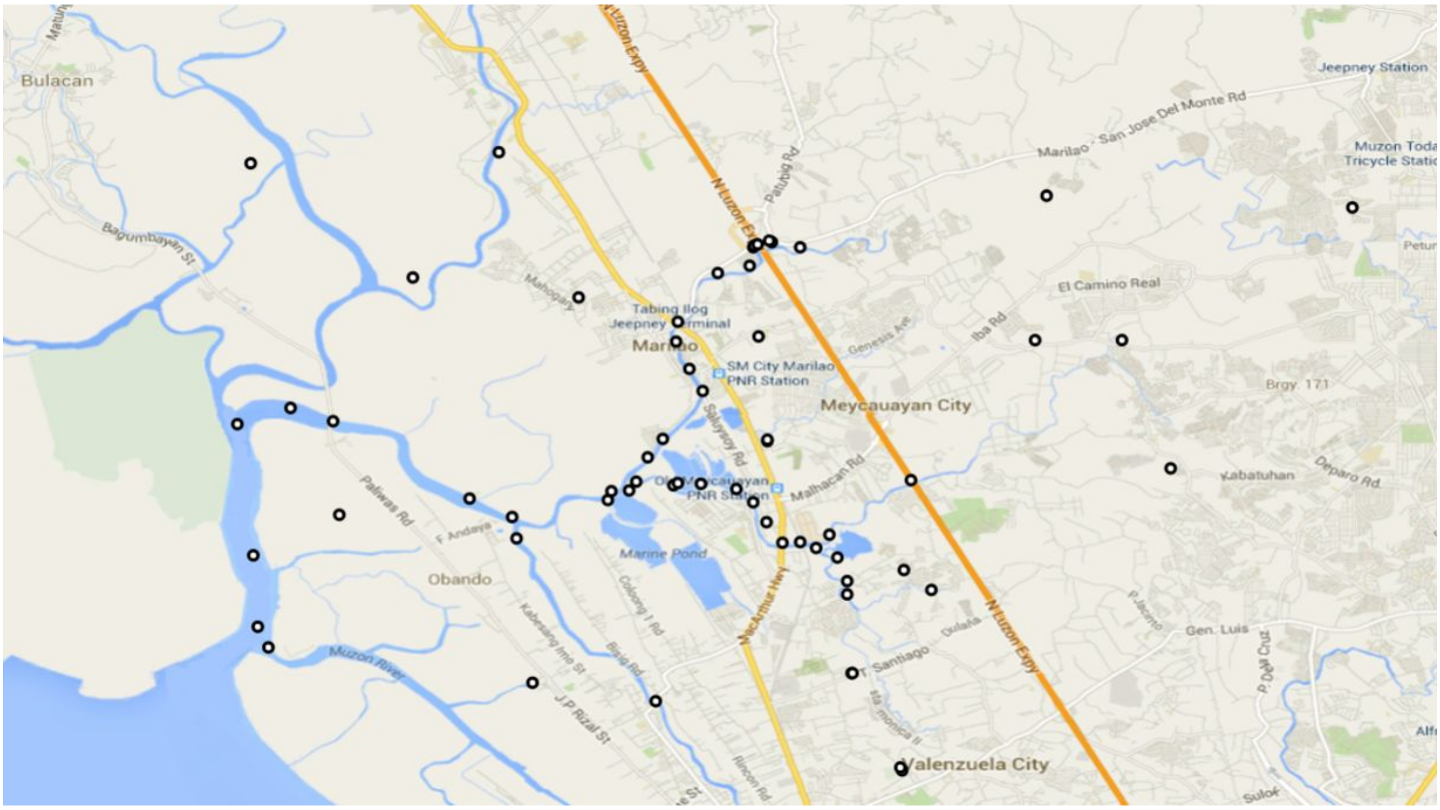

Figure 1. A sample of river monitoring stations (in white circles) in the MMORS

The problem is formulated as a linear program where the objective is to **minimize cost of cleaning the river** and **meet constraints** for the river quality components that will **satisfy the standards specified** by the Department Administrative Order (DAO) 1990-34 Class C requirement of the Department of Environment and Natural Resources. The said standard labels rivers into classes, and the project's overall objective is to convert the MMORS into a river for the following uses (i.e. Class C):

1. **Fishery Water** for the propagation and growth of fish and other aquatic resources;
2. **Recreational Water** Class II (Boatings, etc.);
3. **Industrial Water Supply Class I** (For manufacturing processes after treatment).

We include constraints that have the minimum and maximum allowable content (in mg/L) of heavy metals in a liter of river water. A copy of the said memorandum is in the following link.

Mathematical Formulation

Given

A set $R = \{r_1, r_2, ..., r_m\}$ containing m river quality components
A set $S = \{s_1, s_2, ..., s_n\}$ containing n river stations

A set of parameters:

c_i	cost of lowering river quality component i over a liter of water
a_i	amount of river quality component i lowered over a liter of water
x_i	unknown number of times that the river quality component i will be lowered
C_{ijk}	amount of river quality component i in river station j at time k over a liter of water
$minC_i$	minimum value of river quality component i over a liter of water
$maxC_i$	maximum value of river quality component i over a liter of water
V_j	current volume at river station j in liters

Required

Minimal standard case	Minimize total cost $TC = \sum_{i=1}^{m} (c_i \times min_{x_i})$. Subject to: $a_i \times min_{x_i} \geq (\sum_{j=1}^{n} C_{ij}) + (minC_i \times n), \ \forall i \in R$
Maximal standard case	Minimize total cost $TC = \sum_{i=1}^{m} (c_i \times max_{x_i})$. Subject to: $a_i \times max_{x_i} \geq (\sum_{j=1}^{n} C_{ij}) + (maxC_i \times n), \ \forall i \in R$

There are two versions of the optimization problem to consider for the ranges of the standards needed. We need to consider the costs to achieve the minimum requirement of the river quality component as well as its maximum requirement. In this specific case, the minimum value for all river quality components are 0 but can be changed from time to time.

Significance and Historical Context

The MMORS is one of the dirtiest river systems in the world, as tagged by Blacksmith Institute in 2007 in a report called as 'Dirty 30'. Years later, after government impunity of industrial polluters, the problems of the river system still persists. Different non-government organizations such as Pure Earth (formerly Blacksmith Institute) are doing ways to mitigate river wastes and therefore, further damage from the industries surrounding the river system.

Another important thing to mention is that the MMORS is also has a river delta (river mouth) directly connecting to the Manila Bay. Therefore, all effluents (or waste products) coming from the site will also be received by the Manila Bay and its communities. Most of the people in the area, especially in Navotas and Valenzuela in the National Capital Region, are involved in catching fish products (especially *tilapia*) in the area.

Data that is to be produced in this project is going to be used in the local and national scales. In the local scale, it can be used to budget the river remediation practices in the coming years. In the national scales, data can be used as a benchmark to replicate the same methodologies to other river systems that are close to having the same fate as that of the MMORS.

Meycauayan City and Marilao, Philippines

Potentially Affected People:	Type of Pollutant:	Source of Pollution:
250,000	Hexavalent chromium, other heavy metals, pesticides, sewage, solid waste and tannery waste	Automobile and industrial emissions

The Problem:

Industrial waste is haphazardly dumped into the Marilao, Meycauayan and Obando River system, a source of drinking and agricultural water supplies for the 250,000 people living in and around this suburb of Manila. The river system is extremely polluted due to wastes received from tanneries, gold and precious metals refineries, and legacy lead smelting waste, and numerous municipal dumpsites. Substantial contamination also results from small-scale lead recycling facilities along the river and from the many tanneries that dump untreated hexavalent chromium-laced wastewater into the river.

Health Impacts:

The dumping of toxic wastes into the river has had a severe effect on the health of the local population with complaints of nausea, eye irritation, and various respiratory ailments. The river also feeds directly into the Manila Bay, and its effluents contaminate local fishing areas, further endangering health.

Status of Clean-Up Activity:

There has been considerable local effort to deal with the main sources of pollution, resulting in the creation of a coordinating body to encourage and guide clean up of this river. This stakeholder group, which has been instigated and supported by Blacksmith, includes senior representatives of the federal government, the local municipality, industries from the area and community groups. A process has been started to collaboratively implement private and public remediation efforts over the next several years and efforts are ongoing to obtain national and international financial assistance. 2006 successes include a tannery waste treatment plant paid for by the Manila Tanneries Association. In addition, Stakeholder group members, Philippines Recyclers Incorporated (PRI), has committed to strictly regulate treatment of lead battery waste stockpiles. Strong support from political leadership in the Philippines has been very important in generating momentum for the clean-up process.

Figure 2. Dirty 30 Report Snippet for the MMORS

The data sources for this project has been generously provided by Pure Earth. The project page for the river rehabilitation can be found here. This requirement will fall on the Component 2 of the project, which seeks to find ways in minimizing the cost of river remediation activities. Concurrently, there is also an involvement of trends analysis of river quality components for the Component 1 of the project. (This can also be a special problem/thesis topic.)

Specifications

Ultimate Optimizer

Provide an interface where the user can specify the **objective function**, the **goal** (to minimize or to maximize) and the allowable **constraints**. Specify the necessary syntax for the different inputs of your system. After specifying all the necessary information, the user will instruct the system to start solving (by pressing a button, etc.).

Implement a program that solves the optimization problem using the simplex method. The tableau and the basic solution for each iteration must be placed in **comma separated files** in a folder named `iterations`, with each file named iteration_<number>.csv (e.g. `iteration_1.csv`). The **final solution** and **resulting value** of the objective function must be identified. **You should only use R as the programming language.**

River Quality Cost Projector

For this feature, provide an interface where the user can select any or all (Check All or Reset) of the river monitoring stations. Make sure that changing the input is an easy task for the user. The following are the aspects of the data input which should be changed:

c_i a_i	If there is a new method that can be used in determining the value of the river quality component in a liter of water, its cost c_i and its efficiency in remediating that component should be considered, which is measured by a_i.
C_{ijk}	The amounts of the river quality components should easily be changed because there is a time aspect in the data set.
$minC_i$ $maxC_i$	If the standard for the minimum and maximum amount of river quality components are available, these can be changed if a new administrative order has been introduced. This can also be changed if there will be an existing international standard.

The final output of your program must be a table which contains:

- the corresponding costs for treating r, $\forall r \in R$ over the set S (i.e. min_{x_i} and max_{x_i}); and
- the minimum and maximum amount of river quality monitoring components $\sum_{j=1}^{n} V_j \times min_{x_i}$ and $\sum_{j=1}^{n} V_j \times max_{x_i}$ that can be treated.

Please refer to the test case for more information.

The value of these amounts may be exceedingly large, because they are in milligrams. It will be intuitive to convert such values into kilograms instead.

You shall use your Ultimate Optimizer in doing this task, and you shall use any programming language as your interface. You should therefore know how to integrate R over your language of choice. **Be wary of the difference between the proportions of the units in the data set. You have been warned.**

Any river monitoring station may be selected, and some solutions may be infeasible because of the non-satisfaction of constraints.

Incentive

The current data is given with a date format, specific to the month and year. The objective of this incentive is to optimize the cost, in a specific time frame within the year. To place this problem in context, the following research question is to be asked: "When will be the optimal time to conduct river remediation activities In the context of the MMORS?"

Potential applications of this research question will help policy makers in identifying and budgeting resources to conduct river remediation activities. It will also help environmental planners in identifying the trend of the increase or decrease of the river quality components.

You will decide on how to interpret the above research question and to provide a decent solution to the above problem.

Perks

The student with the acceptable and exemplary output as decided by the laboratory instructors will have the opportunity to submit a paper in a national or international conference.

Data Sets

River Quality Components

The following river quality components to be minimized subject to the standards are located in the first sheet of the link below.

https://docs.google.com/spreadsheets/d/19Drz5siOaWq67pIvlD4bECoQ19SIWjskDGPc7WzXFdQ/edit?usp=sharing

River Station Data

For the following data set, which is located on the third up to the last sheets, if you are not considering to do the incentive, you should use the data from March. All units are in milligrams per liter (mg/L). The link also contains the volumes of the river monitoring stations, which is found in the second sheet. The link for the said data set is located below.

https://docs.google.com/spreadsheets/d/19Drz5siOaWq67pIvlD4bECoQ19SIWjskDGPc7WzXFdQ/edit?usp=sharing

Test Cases

Please refer to the link below for the test cases.

https://docs.google.com/spreadsheets/d/17Z86NeGiiKDJF2sh0HTxH66lj4kM22DzAi_ONtj938E/edit?usp=sharing