Programming Competition Case

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1. Background

In 2019 alone it was reported that there were 4,000 forest fires that burned 1.8 million hectares of land across Canada [1]. These numbers are not the worst Canada has experienced but there is an increasing trend in the frequency of forest fires across the country. It is only appropriate that each province does what they can to help predict and prevent the spread of future forest fires.

In the province of New Brunswick, according to the New Brunswick Forest Fire Watch [2], the 10-year average of forest fires between 2011-2020 was 198 fires with an average of 332.4 hectares of forest burnt. These numbers pale in comparison to the nationwide statistics, however, the province believes that investing in a program to predict the likelihood of fires occurring could bring down the national rates and mitigate future catastrophes. The province of New Brunswick is also extremely focused on protecting and preserving its many key locations such as national landmarks and historical sites that could potentially be damaged.

Figure 1: Fundy National Park [3].

Figure 2: Kouchibouguac National Park [4].

With the increasing danger that climate change presents to our environment, the province of New Brunswick has determined that action must be taken to help predict and combat forest fires. The province has been divided into approximately 73,000 fire zones, each covering 1 km^2 of land. The province intends to use each of these fire zones as a means of predicting, tracking, and analyzing forest fires that occur within them. With the data that each of these fire zones will provide, the province can then allocate firefighting resources as required. This will allow for predicted forest fires to be combated in the most efficient way possible.

The province is undecided as to what information is useful for this type of project and has thus prepared many data files. Having many concerns as to the execution of the project, the Government of New Brunswick has decided to contract a group of engineers to work on the design. The province hopes that with the help of a team of engineers, a program can be developed that can use the data effectively.

2. Competition Challenge

The province of New Brunswick has contracted you, a group of engineers, to develop a software implementation that will generate a forest fire prediction plan.

Several large data sets pertaining to forest fires in New Brunswick have been collected and will be supplied. The province of New Brunswick wants the likelihood of a forest fire occurring to be represented by a probability percentage. This means that it is up to your group of engineers to develop a metric. The metric will be your group's method of mathematically quantifying the probability of a fire occurring in any given fire zone. The provided data sets are in a .csv format, where each cell represents a 10 km x 10 km fire zone and the data within that cell represents the given data for that fire zone. These data sets are:

- 10-year average of forest fires
- Temperature predictions for upcoming dry season
- Distance to nearest body of water (km)
- Number of fireworks set off within the past year
- Density of foliage/forests
- Density of population
- Annual camping traffic (campers / year)
- Key locations
- Fire station locations
- Number of convicted arsonists

The developed software implementation should be able to read in these large data sets from the files and implement the designed forest fire probability metric. This metric, once explained and defended to the New Brunswick Forest Fire Watch, will then be used to help the province understand which areas are the most at-risk of forest fires.

If your team of engineers can successfully meet the province's requirements for the forest fire probability code, then the province will choose to extend the code to predict where the forest fires are most likely to occur. Once predictions have been made, the province also wants to be able to help the regions prepare as much as possible. Therefore, the designed software should then be able to take the probability data previously calculated and, using the input data set of key locations (cities, towns, monuments, parks, etc.) based on fire zones, determine which key locations are the most at-risk when a forest fire occurs. This will allow the province to equip these key locations with the required resources to help combat a possible forest fire.

The province's final goal for your team is to be able identify local fire fighting resources that should be used, that way it makes managing and dispatching these resources quicker and easier. As part of the data sets provided by the government, there is a .csv file that describes several locations of fire stations scattered across the province in a select few fire zones. There are three different types of fire stations within the province:

- Type A (represented by an "A" in cell):
    - Uses water planes
    - Can respond to fires within 100 km in a maximum of 30 minutes

  - Travel great distances quickly
  - Requires nearby access to water
  - Can function in all conditions
- Type B (represented by a "B" in a cell):
  - Has well-kept fire trucks equipped with hoses and ladders.
  - Can respond to fires within 80 km in a maximum of 1.5 hours
  - Can only function in cities or towns (fire hydrant access)
- Type C (represented by a "C" in a cell):
  - Has a large fleet of ATV's
  - Each ATV has a limited amount of water at its disposal
  - Travels back to fire station to refill water
  - Can respond to fires within 40 km in a maximum of 2 hours
  - Can function in all conditions

The program should allocate each fire station to AT MOST a single key location. It is important to note that some key locations may require more access to firefighting resources based on its risk. All key locations should have at least one fire station allocated to them. The criteria for which decides what makes a particular fire station suitable for a key location must be described.

This software will prove to be an extremely valuable and important tool that the Government of New Brunswick can use to help combat the danger presented by forest fires. The government requires the code to be well documented as described in the design deliverables.

3. Specific Solution Objectives

This problem is divided into 4 stages:

1. **Stage 1**: Determine a forest fire probability metric
    a. This metric must be mathematical in nature.
    b. May only use the provided input data sets as variables in the metric (you do not have to use all the different data sets).
    c. Must justify in detail, the design choices made for the forest fire probability metric.
    d. Time must be dedicated in your presentation to explaining this metric to the judges.
2. **Stage 2**: Implement the forest fire probability metric into your program
    a. Program should be able to read the data from each data set that is required for the designed metric and calculate the metric for each fire zone cell.
    b. The output should consist of an M by N table (.csv) where each cell represents a fire zone and the data within that cell is the result of calculating the forest fire probability metric for that cell.
3. **Stage 3**: Determine which key locations are the most at-risk
    a. Program should be able to read the key locations input data set and use the cell map of forest fire probabilities (calculated in Stage 2) to determine which key locations are the most at-risk from forest fires.
    b. The criteria for which determines if a key location is "at-risk" or not must be determined, properly implemented, and explained.

c. The output of this stage should consist of an M by N table (.csv) where each cell represents a fire zone. This time, the only cells that have values in them should be the cells that originally housed key locations. The values in these cells will range from [1, N] (where N is the number of key locations). A value of 1 represents that this key location is the most at-risk of forest fires, and a value of N represents that this key location is the least at-risk. A specific value can only be used ONCE in the entire map; therefore, each key location will have a unique value representing how at-risk it is of forest fire.

4. **Stage 4**: Allocate firefighting resources to at-risk key locations
    a. Program should be able to read the fire station locations data set and use the cell map of at-risk key locations (calculated in Stage 3) to determine which firefighting resources should be allocated to each key location.
    b. Must consider the 3 different types of fire stations as previously discussed when allocating firefighting resources.
    c. The output should be the key location that the specific firefighting station has been assigned to. If no location has been applied, then mark the station as STBY (i.e., that station is on standby).

4. Further Expectations/ Deliverables

You will have **8 hours** to complete this competition. At the 8-hour mark, your team must provide all the outputs from the programs, your finalized code, and your group's presentation. Anything not in the folder before the deadline will not be considered as part of your submission.

Code Deliverable:

- All your code needs to be in the provided folder before the 8-hour deadline in order for it to be considered.
- Basic instructions must be provided on how to compile and run your code.
  - You must specify the language and version your code uses.
  - You can assume that anyone who runs the code has the appropriate language installed.
  - A list of required packages is advised (i.e., Pandas, NumPy).

Presentation Deliverable:

- You must discuss your group's chosen metric.
- You should discuss choices made in the code, for example what language was chosen, and what packages where used.
- Discuss your criteria behind identifying what is considered an "at-risk" location.
- The presentation should review any and all results that could be collected from your team's program.
- You need to show some measure of CPU usage and memory (RAM) usage. This can be done by taking the time from start to completion of the program, identifying the peak CPU load, and the peak RAM load that the program causes.

- Only presentations submitted in the provided folder will be used in the presentation period. No work may be done on the presentation deliverable after the deadline has passed.

5. Judging Metrics

The judges will be using the matrix shown below in Figure 3 to determine how well your team meets expectations. The judging metrics, and all competition rules can be found in the CEC 2022 Rule Book.

Programming Judging Matrix		
Strategy/Algorithm	Simplicity	/10
	Ingenuity	/10
	Ability to Achieve Desired Outcome	/15
		/35
Code	Structure	/10
	Consistency	/5
	Readability	/10
	Efficiency	/10
		/35
Resource Management	Memory Usage Efficiency	/5
	Program's CPU Usage	/5
		/10
Presentation	Design Process and Justification	/7
	Design Critique	/4
	Voice, Articulation and Timing	/4
	Visual Aids	/2
	Response to Questions	/3
		/20
Deduction Total		
Total		**/100**

Figure 3: Programming Judges Rubric.

Please be aware that there are certain actions that can cause your team to incur penalties, therefore you should be familiar with the penalty matrix in Figure 4.

Programming Point Penalties	
Plagiarism	Elimination
Documents Received After Deadline	-50
Absent Team Member	-25
Entering presentation room before allotted time (after first offense)	-10
Total	

Figure 4: Programming Penalty Rubric.

6. Definitions

Forest Fire Probability Metric: A mathematical formula that considers the numerical values of several variables to calculate a result between 0 and 1. This result represents the probability of a forest fire occurring provided the values of the used variables.

7. References

[1] https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/how-does-disturbance-shape-canad/indicator-forest-fires/16392

[2]https://www2.gnb.ca/content/gnb/en/news/public_alerts/forest_fire_watch.html

[3] https://www.pc.gc.ca/en/pn-np/nb/fundy

[4] https://www.pc.gc.ca/en/pn-np/nb/kouchibouguac