FIT5216: Modelling Discrete Optimization Problems
Assignment 1: Blast Planning

1 Overview

For this assignment, your task is to write a MiniZinc model for a given problem specification.

- Submit your work to the MiniZinc auto grading system (using the submit button in the MiniZinc IDE).
- Submit your model (copy and paste the contents of the .mzn file) using the Moodle assignment.

You have to submit by the due date (27th March 2021, 11:59pm), using MiniZinc and using the Moodle assignment, to receive full marks. You can submit as often as you want before the due date. Late submissions without special consideration receive a penalty of 10% of the available marks per day. Submissions are not accepted more than 10 days after the original deadline.

This is an **individual assignment**. Your submission has to be **entirely your own work**. We will use similarity detection software to detect any attempt at collusion, and the **penalties are quite harsh**. If in doubt, contact your teaching team with any questions!

2 Problem Statement

Your task is to plan a set of blasts in a mine, in order to mine valuable minerals. The area for mining is a rectangle which is subdivided into $W \times H$ cells. You need to decide a set of locations to blast. Each cell has a *cost* to blast there, and an associated *reward* to mine minerals there. A negative reward means that your blasting cannot be made in that cell.

The goal is to find the most profitable blasting sites. For task (a) you are planning a fixed number of blasts. For task (b) you are planning a bounded number of blasts with a given maximum number. The profit is the sum of the rewards minus the sum of the blasting cost.

Each blast location must be at least 3 cells distant from any other blast: e.g. have a Manhattan distance of at least 3.

You have a given budget, which is the maximum cost you can spend (the sum of all costs of the cells that you blast). The company will mine the minerals from the blast locations, and those in the neighbouring orthogonally and diagonally adjacent cells. A negative reward in an orthogonally or diagonally adjacent cell means that the ground is unstable, and instead of mining minerals, you have to reinforce the adjacent blast.

Input data is given in MiniZinc data format:

W = $\langle$ *width* $\rangle$;
H = $\langle$ *height* $\rangle$;
cost = $\langle$ *2D* $W \times H$ *array of costs* $\rangle$;
reward = $\langle$ *2D* $W \times H$*array of rewards* $\rangle$;
length = $\langle$ *length (limit)* $\rangle$;
budget = $\langle$ *build budget* $\rangle$;

Here is a sample data set:

```
W = 9;
H = 5;
cost = array2d(1..H,1..W,[ 3 | r in 1..H, c in 1..W]);
reward = [| 4, 0, 0, 0, 0, 0, 0, 0, 0
          | 0, 6, 0, 0, 2, 0, 0, 4, 0
          | 0, 0, 0, 0, 0, 0,-4, 0, 0
          | 0, 0, 4,-2, 0, 0, 0, 0, 0
          | 0, 0, 0, 0, 4, 0, 0, 2, 0
          |];
limit = 6;
budget = 18;
```

On this 9x5 grid, the cost for blasting each position is 3 and the reward data is given by

4								
	6			2			4	
						-4		
		4	-2					
				4			2	

and the blast limit is 6 and the budget 18. Note that in general the costs may be different for each cell.

Part A - Fixed Number of Blasts

Create a model `blast.mzn` that takes data in the format specified above and decides on a exactly `limit` different blast locations.

Here is a sample solution. The blasts are represented in light blue, the additionally mined areas in light gray.

4								
	6			2			4	
						-4		
		4	-2					
				4			2	

Note that there are 6 blasts, as required. None of the blasts is closer than 3 squares to another blast, and no blast is on a negative reward (red) cell. The total reward is the sum of the light blue cells (0), plus the light gray adjacent cells (sum=24), which adds up to 24. The total cost is 18, so the overall profit is 6.

Your model must define the positions of the blast cells as x and y coordinates, together with the total profit. One correct output for the solution above is

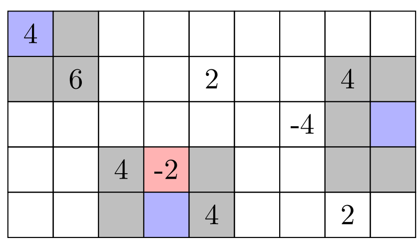
```
x = [1, 9, 6, 5, 9, 2];
y = [2, 1, 5, 1, 4, 5];
profit = 8;
```

In order to compute the reward, you may want to decide for each cell whether you can collect a reward from it, i.e., whether it is on the adjacent to a blast location. Once you have that information, it is easy to add up all the rewards.

Note that you will not be able to obtain full marks by just answering part A. Some problems will have no solution, whereas using part B they have a solution.

Part B - Bounded Number of Blasts

Modify your model `blast.mzn` to treat `limit` as a bound on the maximal possible number of blasts. For example an optimal profit for the example data is illustrated by the solution



The number of blasts in 3 with cost of 9. It only directly covers (light blue) the top left point with a reward of 4, and has adjacent rewards (light gray) of 18, while touching the -2 light red cell. The total reward is therefore 20, for a total profit of 11.

To model this extension, unused blast cells must be defined as having x and y coordinate 0. All the unused positions must occur at the end of the x and y lists. So a correct output for this solution is:

```
x = [4, 9, 1, 0, 0, 0];
y = [5, 3, 1, 0, 0, 0];
profit = 11;
```

3 Instructions

Edit the provided `mzn` model files to solve the problems described above. You are provided with some sample data files to try your model on. Your implementations can be tested locally by using the *Run+check* icon in the MiniZinc IDE. Note that the checker for this assignment will only test whether your model produces output in the required format, it does not check whether your solutions are correct. The checker on the server will give you feedback on the correctness of your submitted solutions and models.

4 Marking

The marks are automatically calculated.

- For most instances you can get a maximum of 0.75 for part A and 1 (full marks) for part B.
- For some instances you can get full marks with part A.
- For some instances you will always get 0 with part A.

The submission has 10 marks for locally tested data and 12 for model testing, for a total of 22 marks.