CC58 - Topics in Computer Science
Homework 2: Constraint Programming

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1 Rules

- You can work in groups of maximum 3 people.
- You should write a report of 3–4 pages, in which you describe your model.
- You should return the report by the first session of week 12 at midnight at latest. Attach the code to the report. Both should be uploaded to blackboard.
- Session of Wednesday November the 3th will be devoted to present those projects.

2 Project

2.1 Solving a real-world problem

Let's consider a factual and highly topical problem:

A pandemic is rising. Vaccination centers must organize quickly to treat all the people.

Our country needs an algorithm which matches unvaccinated people and vaccination centers together given multiple criteria such as patient age, location, center capacity and number of dose, etc.

This map of the pandemic (see Figure 1) illustrates the output of our algorithm which will match unvaccinated people with vaccination centers. There are several frameworks for constraint solving. Google Optimization Tools (a.k.a., OR-Tools) is an open-source software suite for solving combinatorial optimization problems. Our problem will be modeled using this framework in Python.

2.2 Parameters

For now, let's simplify the problem to 4 parameters:

1. Location of people.
2. Age of people
3. Location of centers.
4. Capacity of centers.
5. Number of doses.

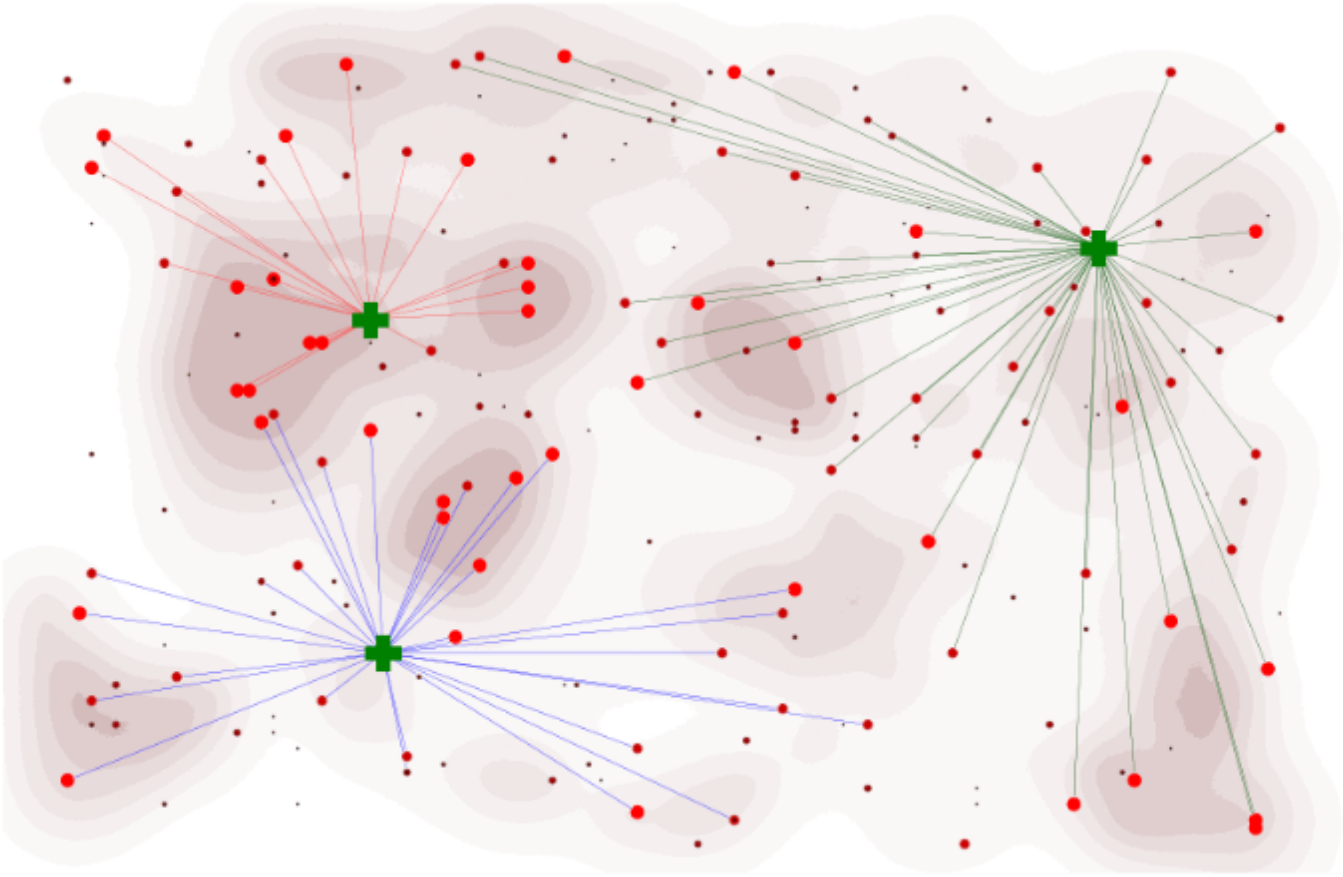

Figure 1: Map of the pandemic, reduced to 2 parameters: location of patients and centers and age of people.

2.3 Variables

A constraint satisfaction problem consists of a set of variables (X) that must be assigned values (D) in such a way that a set of constraints (C) is satisfied:

- Let V be the set of vaccination centers.
- Let C_i be capacity of center i.
- Let P be the set of patients.

The set of variables is defined as:

$$x_{ijk} \in \{0, 1\} \text{ where } (i, j, k) \in V \times C_i \times P$$

If in the center i, the vaccine j is taken by the person k then $x_{ijk} = 1$. In order to associate each vaccine of a center to a person, the goal is to find a set of variables that satisfies all of our constraints.

2.4 Hard constraints

Hard constraints define the core of our model. If these constraints can't be solved, then the problem has no solution, thus they are essential:

- Each vaccine must be applied to at most a person.
- There must be at most a single center assigned to every person.
- Vaccinated people must not be asigned to any center.
- People that have been infected should not receive the vaccine, up to 3 months later.

2.5 Soft constraints

Soft constraints are preferences (highly desired): our solution must try to satisfy them as much as possible, yet they are not essential to find a solution:

- Every unvaccinated person should be assigned with a vaccine.
- Every person should be handled by the nearest center.
- Older people should be assigned first.

2.6 Data

The students must look for real data (i.e.,**latitude and longitude**), in order to design 2D maps for:

- Vaccination centers: Data1
- Criteria for being vaccinated:
  1. Age: according to the age range, the people can be assigned to a vaccine.
  2. Infection: if a person has been infected, he/she must not be assigned to a vaccine.
  3. Vaccinations: according to the number of dose, the people can be assigned to a vaccine, if already both doses have been applied, no assignation is possible.

Description	Points		
	Good	Average	Deficient
Data			
Obtain real geolocalization data of at least 30 vaccination centers	1	0.5	0
Obtain/generate geolocalization data of at least 10,000 people in 5 districts	2	1	0
Problem			
Definition of the problem	2	1	0
CSP model			
Formal model of a $CSP = \{X, D, C\}$	2	1	0
Code	2	1	0
Heuristics			
Use and comparison of Variable Heuristic and Value Heuristic	2	1	0
Explanation of the best results	1	0.5	0
Visualization			
Develop a GUI that allows to select criteria (age, quantity, ...)	3	1.5	0
Visualize the results into a real map	3	1.5	0
Conclusion			
Describe your most promising results	1	0.5	0
Why using CP in this kind of problem is relevant? Machine learning techniques can tackle this problem? If so, why not use them besides CP?	1	0.5	0

Table 1: Points