1ST PRACTICAL HOMEWORK

Optimization methods 2017/18 Deadline: Sunday, 22.4.2018

Car charging problem **[10 points]**

European Commission decided to substantially increase usage of electrical cars to dramatically reduce CO_2 emissions. This decision is a great victory of ecologic organizations, but electricity grid operators are afraid that their distribution grids have insufficient capacity to transfer electricity needed to change all cars. So, they performed an extensive study to carefully analyze consequences of the new European directive which conclude that electrical cars increase the fluctuation of electricity demands and the capacity of current electricity grid is insufficient to cover peak electricity demands. Grid operators decided to install electrical batteries to balance fluctuations of demands. Now, they need our help to find an optimal locations of batteries.

The electricity grid can be modelled as a undirected graph $G = (V, E)$ on n vertices $v_1, v_2, \dots, v_n$ and m edges $e_1, e_2, \dots, e_m$. This graph is very sparse and contains many leaves. There are d charging stations located in pair-wise different vertices $v_{s_1}, v_{s_2}, \dots, v_{s_d}$. Since the task is to plan distribution of electricity during a sufficiently long horizon, this horizon is split into t time intervals. Using the extensive study, grid operators estimated that $a_{i,j}$ kWh electricity will be demanded at a charging station i located in a vertex v_{s_i} during time interval j. For simplicity, only a single power station of an unlimited production located in a vertex v_1 is considered in the model.

Grid operators are fully aware that batteries cannot located everywhere; for instance, it is impractical to place a battery in a vertex of degree at most 2. Considering all technical and legal restrictions, grid operators provide a list $v_{b_1}, v_{b_2}, \dots, v_{b_p}$ of vertices where batteries can be installed. The task is to determine capacity (in kWh) of batteries in these vertices. Note that the capacity of batteries cannot be changed during the planning horizon, batteries cannot be transported between vertices, and all batteries are fully discharged in the beginning of the first time interval. Furthermore, electrical cars cannot be used to transport electricity neither in time nor in space, i.e. car charging demands must be satisfied in a given vertices at a given time interval.

In summary, the task of this homework is to write a program which using GLPK solver for linear programming calculates an optimal size of all batteries and transmission of electricity through every cable at every time interval such that

- all car charging demands are fulfilled,
- capacity constrains of cables and batteries are satisfies, and
- the sum of capacities of all batteries is minimized.

Input format

A given file with input data has the following format. The first line contains 5 integers "`n m p t q`"where n is the number of vertices, m is the number of edges, p is the number of possible locations for batteries, t is the number of time interval and q is the number of charging requests. Next m lines determine all edges: the i-line contains 3 integers "`l r c`"meaning that electricity cable e_i joining vertices l and r has capacity c. Next line contains p integers giving possible locations for batteries. Each of the last q lines contains 3 integers "`j i a`"which says that the car charging demand in a vertex v_i at time interval j is a. Unspecified charging demands are assumed to be zero.

Example:

```
6 6 1 2 4
1 4 1
3 4 4
1 3 5
1 2 1
2 3 4
5 6 8
3
1 4 1
1 3 1
2 4 5
2 2 5
```

Output format

The output of a program must contain the following section which starts by the following line.
`#OUTPUT:`
Next line must contain the sum of capacities of all batteries. Next t lines contain determine energy transmission at one time interval and each of these line contain m numbers "`f1 f2 f3 ... fm`". The i-th number f_i on j-th line is energy transmission through an edge $e_j = \{v_l, v_k\}$ at time interval t where $l < k$. In order to specify the direction of electricity flow, the value f_i is positive if energy flows from the vertex v_k to the vertex v_l, and f_i is negative if energy flows from the vertex v_l to the vertex v_k. The result section must be terminated by the following line.
`#OUTPUT END`

If a given instance has no feasible solution, the a program must output the following line (printed automatically by glpsol).

```
PROBLEM HAS NO PRIMAL FEASIBLE SOLUTION
```

Output for the example input.

```
#OUTPUT:
3
-1 0 -4 0 0 0
-1 -4 -5 -1 4 0
#OUTPUT END
```

Evaluation

Students are expected to submit source codes of their program and a document in PDF describing their approach (usually linear programming model used to solve given task). Submitted programs must be able to find an optimal solution and print it described format for every possible input. Buggy programs failing this condition are evaluated by 0 points. The number of points from this homework mainly depends on size of testing input a program solves on a testing computer in a given time. Testing inputs will be similar as example input available on lecture's website.