

Implementation of Graph Algorithms

1 Task Description

In this assignment, you have the option to choose C++, Python, or Java for your implementation to solve the given puzzle.

Hint: All it takes is an algorithm mentioned in this course (with a slight twist).

The graph is undirected!

2 Puzzle

You need to redesign the road system of an imaginary country.

The country is composed of N cities (for simplicity numbered from 0 to $N - 1$). Some pairs of cities are connected by bidirectional roads. We say that there is a path between different cities A and B if there exists a sequence of unique cities C_1, C_2, \dots, C_M , such that $C_1 = A$ and $C_M = B$ and for each index $i < M$, there is a road between cities C_i and C_{i+1} .

The current state of the road network is miserable. Some pairs of cities are not connected by any path. On the other hand, other pairs of cities are connected by multiple different paths, and that leads to complicated traffic routing. You want to build some new roads and destroy some of the already existing roads in the country so that after the reconstruction there will exist exactly one path between every pair of distinct cities. As building new roads and destroying old ones costs a lot of money, you want to minimize the total cost spent on the reconstruction.

You are given three two-dimensional arrays:

- `country[i][j]=1 or 0`: there is an existing road between city i and j if and only if `country[i][j]=1`.
- `build[i][j]`: the cost for building a road between i and j . The values of `build[i][j]` are represented using English letters. A, B, \dots, Z represent $0, 1, \dots, 25$ and a, b, \dots, z represent $26, 27, \dots, 51$. For example, if `build[2][4]=b`, then that means the cost for building a road between city 2 and city 4 is 27.
- `destroy[i][j]`: the cost for destroying a road between i and j . Again, the values are represented using English letters like the above.

Your task is to find and print the minimal cost needed for the road network reconstruction.

You don't need to worry about invalid inputs.

- Sample input 1: 000,000,000 ABD,BAC,DCA ABD,BAC,DCA

Note: 000,000,000 describes the two-dimensional array `country`. ABD,BAC,DCA describes the two-dimensional array `build`. ABD,BAC,DCA describes the two-dimensional array `destroy`. The input format is: three strings separated by spaces; each string contains N parts separated by commas; each part contains N characters.

Sample output 1: 3

Comment: There are three cities, totally disconnected.

- Sample input 2: 011,101,110 ABD,BAC,DCA ABD,BAC,DCA

Sample output 2: 1

Comment: Now the three cities form a connected triangle and we need to destroy one road. Optimal solution is to destroy the road between the cities 0-1 (cost 1).

- Sample input 3: (note: all inputs are on the same line. I just couldn't fit them in one line in this pdf.)

011000,101000,110000,000011,000101,000110

ABDFFF,BACFFF,DCAFFF,FFFABD,FFFbac,FFFdca

ABDFFF,BACFFF,DCAFFF,FFFABD,FFFbac,FFFdca

Sample output 3: 7

Comment: We have six cities forming two separate triangles. Destroy one road in each triangle (costs 1 for each road) and then join the triangles by a new road (costs 5).

- Sample input 4: 0 A A

Sample output 4: 0

Comment: One city is okay just as it is.

- Sample input 5: 0001,0001,0001,1110 Af0j,fAcC,0cAP,jCPA AWFH,WAxU,FxAV,HUVA

Sample output 5: 0

Comment: We have four cities, which are connected in such a way that there is exactly one path between each two cities.

Thus there is nothing to reconstruct.

3 Submission Guideline

You must follow this guideline! Your submission will be marked automatically. Failure to follow this guideline will result in 0.

Your submission should contain exactly one file, which should be named according to the programming language you choose: `main.cpp` for C++, `main.py` for Python, or `main.java` for Java.

You do not need to submit a design.

Marking will be done automatically. The total mark is 10 (1 for compiling and 9 for 9 test cases).

4 Submission Instructions

You are asked to submit via **Gradescope** <https://www.gradescope.com/> (by either direct upload or via a GitHub repository).

You are welcome to resubmit as many times as you wish before the deadline. We will compile and run your code using the specific commands for each language. The specific compilation commands used by the autograder are:

- For C++: `g++ -std=c++11 -o main.out -O2 -Wall main.cpp`
- For Python: `python3 main.py`
- For Java: `javac main.java` followed by `java -cp . main`

It is your responsibility to ensure that your code compiles and runs correctly on the Gradescope system, as compiler versions and environments may vary (e.g. g++ has too many versions, so being able to compile on your laptop does not guarantee that it compiles on the Gradescope system.)