CS302 -- Project 5 -- Letter Dice

- CS302 -- Advanced Data Structures and Algorithms
- Spring, 2020
- Courtesy of James S. Plank (http://www.cs.utk.edu/~plank)
- Original file: **http://www.cs.utk.edu/~plank/plank/classes/cs302/Labs/LabA** (http://www.cs.utk.edu/~plank/plank/classes/cs302/Labs/LabA/index.html)

A prior 302/307 TA Camille Crumpton (2017) posted youtube videos to help with this project -- they are here. (https://www.youtube.com/playlist?list=PLQFSAfh8OMT6qqWxJlcRrK7poAk5VcmxS)

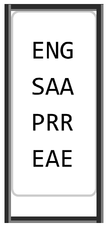
Introduction

NOTE: We recommend that you work with a single partner on this project; however, if you think a group of three will help you complete this remotely (mostly through peer-peer discussion: think our in-class exercises) this will be allowed. You also may work alone.

Suppose you are given some number of "word dice", as in the picture below:

We won't constrain dice to have six sides -- we'll assume that a die may have any number of sides, and that the length of and an input string itself defines the number of sides and possible letters, respectively, of a corresponding die.

For example, let's assume that the above dice only have three sides each -- the sides that you can see. Then, the file **Dice1.txt (http://www.cs.utk.edu/~plank/plank/classes/cs302/Labs/LabA/Dice1.txt)** defines the four dice pictured:



```
ENG
SAA
PRR
EAE
```

The problem you must solve

Your task is to write a program called **worddice**. The input to this program is as follows:

1. The dice available, encoded as described above.
2. A list words to check if they can be spelled using these dice

For example, the word "RAGE" may be spelled using 'R' from the "PRR" die, 'A' from the "SAA" die, 'G' from the "ENG" die and 'E' from the "EAE" die. Similarly, "SEEP" may be spelled with 'S' from the "SAA" die, 'E' from the "EAE" die, 'E' from the "ENG" die and 'P' from the "PRR" die.
However, you cannot spell "PEEN", even though all the letters are there, because you would have to use the "ENG" die for both the 'E' and 'N'.

Input/output

The dice described above must be present in an input file. Each die may have any number of letters, and, within a file, the dice may all have differing numbers of letters. The word list is simply a second file containing words, one per line.
For each word in the word list, your program should print out one of the following:

- If the word cannot be spelled: "Cannot spell *word*".
- If the word can be spelled: The order of the dice used to spell out the word, then the word. The dice are numbered starting with zero.

Here is a command line session example using the above dice and target words. Note "GASP" can also be spelled, as shown below in the requested output format:

```
UNIX> cat Dice1.txt
ENG
SAA
PRR
EAE
UNIX> cat Words1.txt
RAGE
SEEP
PEEN
GASP
UNIX> worddice Dice1.txt Words1.txt
2,1,0,3: RAGE
1,0,3,2: SEEP
Cannot spell PEEN
0,3,1,2: GASP
UNIX>
```

Organizing the program

This is an example of a bipartite matching. For each word, set up a graph that matches dice to letters of the words. For example, here are the above dice with the word "RAGE":

Dr. Plank has included double-edges for the duplicate letters. Your program can eliminate these if you want, since duplicate letters don't help you at all and just make your program run slower. We'll accept either way.

You want to find a *matching* of this graph that is composed of edges that connect two nodes, where no edge is incident to the same node.

To do this, you convert the graph into one in which network flow will solve the problem: a source node connected to each die, and a sink node connected to each letter of the word:

Finding the maximum flow will discover the matching if it exists. Here is the flow/matching in this example:

Your program should use the Edmonds-Karp algorithm to determine maximum flow. The fact that all edges have weight one makes this easier.

Dr. Plank's implementation is slow for two reasons. First, he creates and destroys the graph with each word. It would be faster if he never deleted the source and dice nodes/edges. Second, when he created the edges to each letter of the word, he used the **Find()** method on the dice strings. That is inefficient as compared with other potential optimizations, but probably what you will also use given what we have covered in 140/302.

Hint: read the input and create the graphs first

The program **readorig** was the first step for both of us -- reading the input, creating the network flow graph, and printing it out. Note, in sample output below from Dr. Plank, his program does not have duplicate edges. This will help get you started.

```
UNIX> readorig Dice1.txt Words1.txt
Node 0: SOURCE Edges to 1 2 3 4
Node 1: ENG Edges to 7 8
Node 2: SAA Edges to 6
Node 3: PRR Edges to 5
Node 4: EAE Edges to 6 8
Node 5: R Edges to 9
Node 6: A Edges to 9
Node 7: G Edges to 9
Node 8: E Edges to 9
Node 9: SINK Edges to

Node 0: SOURCE Edges to 1 2 3 4
Node 1: ENG Edges to 6 7
Node 2: SAA Edges to 5
Node 3: PRR Edges to 8
Node 4: EAE Edges to 6 7
Node 5: S Edges to 9
Node 6: E Edges to 9
Node 7: E Edges to 9
Node 8: P Edges to 9
Node 9: SINK Edges to

Node 0: SOURCE Edges to 1 2 3 4
Node 1: ENG Edges to 6 7 8
Node 2: SAA Edges to
Node 3: PRR Edges to 5
Node 4: EAE Edges to 6 7
Node 5: P Edges to 9
Node 6: E Edges to 9
Node 7: E Edges to 9
Node 8: N Edges to 9
Node 9: SINK Edges to

Node 0: SOURCE Edges to 1 2 3 4
Node 1: ENG Edges to 5
Node 2: SAA Edges to 6 7
Node 3: PRR Edges to 8
Node 4: EAE Edges to 6
Node 5: G Edges to 9
Node 6: A Edges to 9
Node 7: S Edges to 9
Node 8: P Edges to 9
Node 9: SINK Edges to

UNIX>
```

Examples

Dr. Plank has provided a few additional example files:
Dice2.txt (Dice2.txt) and **Words2.txt (Words2.txt)** are small files to test variable-sized dice:

```
UNIX> cat Dice2.txt
E
PITED
FOGCEF
UNIX> cat Words2.txt
DOG
PIG
CAT
DO
TEE
FEE
UNIX> worddice Dice2.txt Words2.txt
Cannot spell DOG
Cannot spell PIG
Cannot spell CAT
1,2: DO
1,0,2: TEE
2,0,1: FEE
UNIX>
```

Dice3.txt (Dice3.txt) is a file with six randomly generated six-sided dice, and **Words3.txt (Words3.txt)** contains all words from the Unix dictionary that have six letters.

```
UNIX> cat Dice3.txt
IBTLCP
DUAQEM
DXLOTN
WMIVQA
NDCLOT
JKCEMR
UNIX> head Words3.txt
AARHUS
ABACUS
ABATER
ABBOTT
ABDUCT
ABJECT
ABLATE
ABLAZE
ABOARD
ABOUND
UNIX> worddice Dice3.txt Words3.txt | head
Cannot spell AARHUS
Cannot spell ABACUS
Cannot spell ABATER
Cannot spell ABBOTT
3,0,2,1,5,4: ABDUCT
3,0,5,1,4,2: ABJECT
1,0,2,3,4,5: ABLATE
Cannot spell ABLAZE
1,0,2,3,5,4: ABOARD
Cannot spell ABOUND
UNIX>
```

Dice4.txt (Dice4.txt) is a file with eight randomly generated dice with between three and seven sides. **Words4.txt (Words4.txt)** contains all words from the Unix dictionary that have eight letters. As **worddice** shows, there are fewer successful spellings in this example:

```
UNIX> cat Dice4.txt
FJZ
BSYQ
WYUTI
SHTXVU
PRAFYBH
LWQCEI
ENLJB
BTJO
UNIX> head Words4.txt
ABDICATE
ABERDEEN
ABERRANT
ABERRATE
ABETTING
ABEYANCE
ABHORRED
ABLUTION
ABNORMAL
ABORNING
UNIX> worddice Dice4.txt Words4.txt | head
Cannot spell ABDICATE
Cannot spell ABERDEEN
Cannot spell ABERRANT
Cannot spell ABERRATE
Cannot spell ABETTING
Cannot spell ABEYANCE
Cannot spell ABHORRED
Cannot spell ABLUTION
Cannot spell ABNORMAL
Cannot spell ABORNING
UNIX> worddice Dice4.txt Words4.txt | grep ':' | head
7,6,4,2,3,5,0,1: BEAUTIFY
1,6,7,2,0,5,3,4: BLOWFISH
7,5,3,6,0,2,1,4: BLUEFISH
6,7,4,1,2,0,3,5: BOASTFUL
5,0,4,3,1,2,7,6: EFFUSION
0,4,6,2,5,7,3,1: FABULOUS
0,6,4,7,5,2,3,1: FEROCITY
0,5,1,7,2,3,4,6: FESTIVAL
```

```
0,2,6,4,7,3,5,1: FIBROSIS
0,6,4,2,3,5,1,7: FLAUTIST
UNIX>
```

The Gradescript

There will be a program called **grader** in the lab directory which is used to determine if your output is correct via matching ours.

Additional requirements

When you are finished implementing your `worddice` implementation, each member must provide a **brief summary** of their **individual contributions** to the project and answer the following question:

1. What is **complexity** of your implementation?

   Explain this by describing which data structures you used and how you used them to implement network flow.

Submission instructions

Please have one team member submit an archive of the following files (not in a subdirectory of the archive) on Canvas to aid us in grading:

1. source files for worddice
2. Text document summarizing the student who is uploading's contributions and their answers to the required question
3. Makefile (even if you use the provided Makefile, please include it)

If you work in a pair, the team member who isn’t submitting the above files should write up a separate document with their contributions and answer and submit only that on Canvas.

Rubric

Your project will be scored as follows:

```
+2    Code is well formatted, commented (inc. name, assignment, and overview), with reasonable variable names
+55   55 points * % of gradescripts passed
+3    Responses, inc. individual contributions
```