Oracle

But First!

Before starting this assignment, please fill out this form to sign cs1950y's collaboration policy: https://goo.gl/forms/Um4ChbOtzcAH2XA82

0. Simple Directed Acyclic Graphs

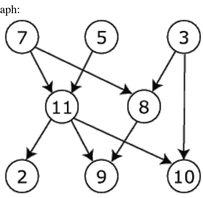
In this assignment, we will be working with a simple, directed acyclic graph. A simple graph does not contain multiple edges between nodes or self loops.

simple graph | *nonsimple graph with multiple edges* | *nonsimple graph with loops*

Image from http://mathworld.wolfram.com/SimpleGraph.html

A directed graph contains edges that run from one node to another (like a one way street). An acyclic graph does not allow the edges in the graph to create a cycle (cannot reach a vertex from itself).

Here is an example of a simple directed acyclic graph:



1. Topological Sort
Given this simple, directed acyclic graph `G = (V, E)`, where `V` are the vertices of the graph and `E` is the edges in the graph, a topological sort finds a linear ordering of vertices, such that for all edges `(a, b)` in `E`, `a` precedes `b` in the ordering.

An example of a topological sort is to determine the order in which a student can take classes given a list of prerequisites. Another example is the order of formula cell evaluation when recomputing formula values in spreadsheets is an application of topological sort. A concrete example is in Part 3 of this assignment. Depending on the graph, many valid topological sorts may exist for each of these problems.

2. The Assignment

You will write two programs for this assignment: a topological sorting program (named `topsort`) and an oracle (named `oracle`).

Implement the topological sorting program using the following pseudocode:

```
function topsort(g): // g = directed acyclic graph
    L = empty list to store ordering
    S = set of vertices with no incoming edges
    while S is not empty:
        u = vertex removed from S
        append u to L
        for each vertex v where edge e = (u,v) in g:
            remove e from g
            if v has no other incoming edges in g:
                insert v in S
    return L
```

Your program should adhere to the input-output specification in Part 3 of this assignment.

Being confident in your software's correctness involves more than just writing code and some unit tests. Many software companies (and computer scientists!) use automated testing to strengthen confidence. For this assignment, you will build an automated testing oracle for topological sorting programs.

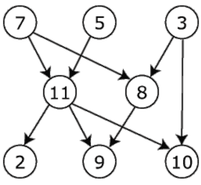
Your oracle will consume the path of a topological sorting program and the number of inputs to generate, `n`. Then, your oracle will generate `n` valid inputs and write each of them to the provided program's standard input. Your oracle will check that each output is in fact a topological sort of the corresponding input and conforms to the specifications in Part 3 of the assignment.

If the provided program always produces a valid topological sort (up to some value of "always"), then your program should exit with status `0`. Otherwise, your program should exit with status `1`. The oracle should not write anything to standard output or standard error. Note that you may assume `n` is valid (a non-negative integer) and all input is well-formed.
Using your oracle, check that your implementation is correct.

You are allowed to use any programming language to implement `topsort` and `oracle` for this assignment, but they need to conform the input-output specification (see next section), so the programs need to be executable on the department machines and be able to read from standard input. That means you can't use languages like Scratch or Pyret. If you need to compile files, you should do so on the department machines or via `ssh` because binaries that work on your computer might not work on department machines. If you don't have a strong preference, we suggest you use Python. If you are using Python, write in Python 3.5. See Part 5 for more information. Additionally, we have provided Python and Java templates for topsort and oracle in the course folder located at `/course/cs1950y/pub/oracle`. These templates partially implement the input and output of the programs and provide a structure for you to follow.

3. Input-Output Specification

Consider the following directed acyclic graph (DAG):



The topological sorting programs consumed by your oracle, including your own `topsort`, will read a directed acyclic graph from standard input in the following form:

```
7 11
7 8
3 10
5 11
3 8
8 9
11 10
11 2
11 9
```

where each line represents a directed edge with each vertex name, an alphanumeric, case-sensitive string of any length, separated by a space (in the example of `7 11`, vertex `7` comes before `11`). Note that the order of lines does not matter. And remember, a valid input should not have cycles!

The programs should write standard output of the following form:

```
3
5
7
11
8
9
10
2
```

where each line contains a vertex name in topological order from top to bottom. Recall that for valid inputs, your program should exit with status `0`, and nothing should be printed to standard error.

While we don't care about efficiency, in order for us to auto-grade your work, both of your topsort and oracle should not take more than 30 seconds to run. The input graph that we will be testing on your topsort will have no more than 200 vertices. When we test your oracle, `n` will be no more than 20.

4. Testing

To test your topsort, you can run

```
./topsort
```

And then type input graph (as a list of edges). Then, press `ctrl-d` to indicate the end of the input. Your topsort should then give a correct answer back.

To test your oracle, try running it on Unix's topological sorting program included on all department machines:

```
./oracle /usr/bin/tsort n
```

where `n` is the number of inputs to generate. Your oracle should exit with status `0` on this program. To ensure your oracle detects incorrect topological sorting programs, try running it on deliberately broken implementations of your creation. Your oracle should exit with status `1` on these broken programs. You can run `echo $?` right after running the oracle to see the status code. Detecting incorrect implementations is just as important as detecting correct implementations! Note that we will not test your program against a topological sorting program that does not terminate[1], but your oracle should finish in a reasonable amount of time.

5. Learning Python
If you are unsure of what language to use, we recommend Python. This online tutorial is a good starting place to become familiar with the language.

6. Handing In

Run `cs1950y_handin oracle` from a directory holding your topological sorting program (named `topsort` or `Topsort.java`) and oracle (named `oracle` or `Oracle.java`), and any additional files you wish to submit. If your `topsort` and `oracle` are binaries, you need to include the source code as well. You should receive an email confirming that your handin has worked.

If you are not registered, you will not be able to run the above handin script. Please zip your files, name it `oracle.zip`, and send it to us at `cs1950ytas@lists.brown.edu`. Please only do so if you cannot register for the course by the due date of the assignment.

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[1] Testing (in finite time!) whether a program terminates is impossible in general (see the Halting problem). Most oracles work around this by setting a threshold (e.g., 3 minutes). If the tested program does not terminate within the threshold, the program is considered to be non-terminating and its process therefore could be killed. However, *you need not implement the check for this assignment*.