Lab 10

Due 7 May

Handout 13
CSCI 136: Spring, 2007
30 April

Scheduling Exams

1 Short Answers

Complete the following problems from the book and turn them in at the start of lab.

Problem 16.2
Problem 16.10
Problem 16.15 (consider `add`, `remove`, `addEdge`)

2 Lab Program

This week, you will write a program to schedule final exams for the registrar so that no student has two exams at the same time. The goals of this lab are to:

- Gain experience using basic graph building and traversal operations.
- Develop a fairly sophisticated algorithm requiring several coordinated data structures.

You will use a *greedy* algorithm to determine an assignment of classes to exam slots such that:

1. No student is enrolled in two courses assigned to the same exam slot.
2. Any attempt to combine two slots into one would violate rule 1.

The second requirement ensures that we do not gratuitously waste exam slots (students would like to get out of here as soon as possible, after all).

2.1 Input File

The input to your program will be a text file containing student class information. For example:

```
Jessica Chung
CSCI 136
MATH 251
ENGL 201
PHIL 101
Ben Wood
PSYC 212
ENGL 201
HIST 301
CSCI 136
Austin Stanley
SOCI 201
CSCI 136
MATH 251
PSYC 212
```

For each student, there are five lines. The first is the name, and the next four are the courses for that student:

- Jessica Chung is taking CSCI 136, MATH 251, ENGL 201, and PHIL 101;
- Ben Wood is taking PSYC 212, ENGL 201, HIST 301, and CSCI 136; and
- Austin Stanley is taking SOCI 201 CSCI 136, MATH 251, and PSYC 212.

We provide small, medium, and large input files in the starter directory

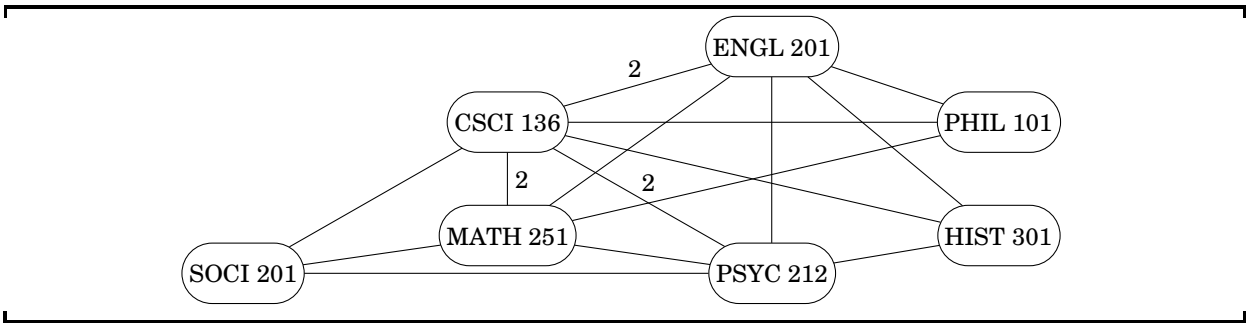
`/usr/mac-cs-local/share/cs136/labs/schedule/`

The output of the program should be a list of time slots with the courses whose final will be given at that slot.

2.2 Algorithm

The key to doing this assignment is to build a graph as you read in the file of students and their schedules.

Each node of the graph will be a course taken by at least one student in the college. An edge will be drawn between two nodes if there is at least one student taking both courses. The label of an edge could be the number of students with both classes (although we don't really need the weights for this program). Thus if there are only the three students listed above, the graph would be as given below (edges without a weight label have weight 1).



A *greedy* algorithm to find an exam schedule satisfying our two constraints would work as follows. Choose a course (say, PHIL 101) and stick it in the first time slot. Search for a course to which it is not connected. If you find one (e.g., HIST 301), add it to the time slot. Now try to find another which is not connected to any of those already in the time slot. If you find one (e.g., SOCI 201), add it to the time slot. Continue until all nodes in the graph are connected to at least one element in the time slot. When this happens, no more courses can be added to the time slot (why?). (By the way, the final set of elements in the time slot is said to be a *maximal independent set* in the graph.)

If there are remaining nodes in the graph, pick one and enter it in a new time slot and then try adding other courses to the same slot as before. Continue adding time slots for remaining courses until all courses are taken care of. Print the exam schedule. For the graph shown, here is one solution:

```
Slot 1: PHIL 101, HIST 301, SOCI 201
Slot 2: MATH 251
Slot 3: CSCI 136
Slot 4: ENGL 201
Slot 5: PSYC 212
```

Notice that no pair of time slots can be combined without creating a time conflict with a student. Unfortunately, this is not the minimal schedule as one can be formed with only four time slots. (See if you can find one!) Thus a greedy algorithm of this sort will give you a schedule with n slots, no

two of which can be combined, but a different selection of courses in slots may result in fewer than n slots. Any schedule satisfying our constraints will be acceptable (although see below for extensions to compute the optimal solution).

2.3 Details

You should represent graphs as adjacency lists. (Why does that make the most sense for this application?) Vertex labels should be the course names.

Here is one possible way to find a collection of maximal independent sets from the graph. Represent each slot by some sort of a list (or, better yet, a binary search tree). To find a maximal independent set for a slot, pick any vertex of the graph and add it to the list. Cycle through all other vertices of the graph. If a vertex is not connected to any of the vertices already in the slot, throw it in. Continue until you have tried all vertices. Now delete all vertices in the slot from the graph. Fill successive slots in the same way until there are no vertices left in the graph.

2.4 Extensions

Please complete at least one interesting extension to the program. I have listed a few examples below. This is also a great opportunity for earning some extra credit by adding any features you find interesting.

1. Print out a final exam schedule ordered by course name/number (ie, AFR 100 would be first, and WGST 999 would be last, if such courses are offered this semester).

2. Print out a final exam schedule for each student, in alphabetical order.

3. Always generate the best possible exam schedule (that is, the one with the fewest number of slots). The best known algorithms for this scheduling problem run in $O(n!)$ time, where n is the number of classes. This is bad. For example, our medium file has 16 classes, and $16! \approx 21$ trillion.

   However, there are nice algorithms to handle small cases. One tactic is to try all possible orderings of the graph's nodes to see which yields the best schedule with our greedy algorithm. (This will in fact be the optimal solution.) You may find the `Permute` class in the starter folder useful for this task. This iterator constructs all permutations of a vector.

   Feel free to explore other approaches as well.

4. Arrange the time slots in an order which tries to minimize the number of students who must take exams in three consecutive time slots. This is trickier than the other options.

Feel free to add other features as well. Be sure sure to indicate in the heading of your program what extras you have included.

2.5 Deliverables

Turn in your well-documented program using `turnin` by the due date.

As in all labs, you will be graded on design, documentation, style, and correctness. Be sure to document your program with appropriate comments, including a general description at the top of the file, a description of each method with pre- and post-conditions where appropriate. Also use comments and descriptive variable names to clarify sections of the code which may not be clear to someone trying to understand it.