Name:

Midterm

CS 121
Software Engineering
Fall 2021

October 20, 2021

Instructions

This exam contains 10 pages, including this one. Make sure you have all the pages. Write your name on the top of this page before starting the exam.

Write your answers on the exam sheets. If you finish at least 15 minutes early, bring your exam to the front when you are finished; otherwise, wait until the end of the exam to turn it in. Please be as quiet as possible.

If you have a question, raise your hand. If you feel an exam question assumes something that is not written, write it down on your exam sheet. Barring some unforeseen error on the exam, however, you shouldn't need to do this at all, so be careful when making assumptions.

Question	Score	Max
1		20
2		20
3		30
4		30
Total		100

Question 1. Short Answer (20 points).

a. (5 points) Java includes both Integer and int. Briefly explain the difference, and explain why Integer is sometimes needed.

> **Answer:** int is the primitive integer, represented directly as a machine word. Integer is the class for *boxed integers*, which are integers that are allocated on the stack. Integer is needed most often so we can store integers in generic collections, e.g., to create a List<Integer>.

b. (5 points) Briefly explain the difference between *checked* and *unchecked* exceptions in Java.

> **Answer:** Any checked exceptions that could be thrown by a method (and are not caught by the method) must be declared by adding a throws clause to the method signature. Unchecked exceptions need not be declared.

c. (5 points) List three potential benefits of choosing a good modular structure for a program.

Answer:

- Developers can work on different modules in parallel.
- A module can be changed without needing to change other modules.
- Each module can be understood independently of the rest of the system.
- Modules can be reused across different programs.

d. (5 points) List three potential disadvantages of using *reflection*.

Answer:

- Extremely verbose, difficult to understand
- May introduce security vulnerabilities
- Misses out on compile-time type checking
- Performance penalty

Question 2. Maps with Lists (20 points). In this problem, you will write part of ListMap, a class that the implements the Map interface using a linked list of pairs, similarly to class LL from lecture. Here is the beginning of the class, to get you started. Throughout this problem, assume there are no duplicate keys in the map.

```
class ListMap<K, V> implements Map<K, V> {
  class Cell {
    K key; V value; Cell next;
    Cell(K key, V value, Cell next) { this.key = key; this.value = value; this.next = next; }
  }
  Cell head; // null if empty
  ...
```

a. (4 points) Write a method V get(Object key) that returns the value corresponding to key, or null if there is no such value. Use equals to compare keys.

Answer:

```
V get(Object key) {
  for (Cell cur = head; cur != null; cur = cur.next) {
    if (cur.key.equals(key)) { return cur.value; }
  }
  return null;
}
```

b. (5 points) Write a method V put(K key, V value) that adds a mapping from key to value to the map and returns null if there was no previous mapping for key. Otherwise, update the previous mapping for key to map to value and return the previous mapping.

Answer:

```
V put(K key, V value) {
  for (Cell cur = head; cur != null; cur = cur.next) {
    if (cur.key.equals(key)) { V prev = cur.value; cur.value = value; return prev; }
  }
  head = new Cell(key, value, head);
  return null;
}
```

c. (5 points) Write a method List<V> values() that returns a list of all the values in the map. A value should appear in the result as many times as it appears in the map. The order of values is undefined.

Answer:

```
List<V> values() {
  List<V> ret = new LinkedList<>();
  for (Cell cur = head; cur != null; cur = cur.next) {
    ret.add(cur.value);
  }
  return ret;
}
```

d. (6 points) Write a method boolean equals(ListMap<K,V> o) that returns true if and only if o contains the same key–value pairs as this, *in any order. Note: Java's Map class doesn't include this kind of deep equality check...but perhaps it should!*

Answer:

```
boolean equals(Object o) {
  for (Cell cur = head; cur != null; cur = cur.next) {
    if (o.get(cur.key) != cur.value) { return false; }
  }
  for (Cell cur = o.head; cur != null; cur = cur.next) {
    if (get(cur.key) != cur.value) { return false; }
  }
  return true;
}
```

Question 3. Design Patterns (30 points). In this problem, we will consider the *Specification Pattern*, in which we use objects to represent predicates. In particular, we will write specs for student transcripts, which we will represent as a map from CS course numbers (Integers) to grade points (Doubles). For example, here is code that creates a transcript t in which a student got an A- in CS 105 and an A in CS 121:

```
Map<Integer, Double> t = new HashMap<Integer, Double>();
t.put(105, 3.7); // A− in CS 105
t.put(121, 4.0); // A in CS 121
```

A *spec* is an object with a boolean check method that tests whether a transcript has some property of interest:

```
interface Spec { boolean check(Map<Integer, Double> t); }
```

For example, here is a spec that returns true if and only if the given transcript includes at least a B- in CS 121.

```
class BMinus121 implements Spec {
  boolean check(Map<Integer, Double> t) {
    if (!t.containsKey(121)) { return false; }
    return t.get(121) >= 2.7; // B− or above in 121
} }
```

a. (4 points) Using BMinus121, write code that prints true if transcript sample has a grade of at least B- in CS 121, and prints false otherwise.

```
HashMap<Integer, Double> sample = ...; // some transcript
```

Answer:

```
System.out.println(new BMinus121().check(sample))
```

b. (8 points) Write a spec CMinusGPA that returns true if and only if the grade point average of a transcript is at least a C- (1.7). Raise an exception (any exception) if the transcript is empty. *Hint: You may want to use method Collection<V> values() of HashMap, which returns the values of a hash map.*

Answer:

```
class CMinusGpa implements Spec {
  boolean check(Map<Integer, Double> t) {
    int cnt = 0; double sum = 0.0;
    for (double d : t.values()) { cnt++; sum += d; }
    return (sum/cnt) >= 1.7;
} }
```

c. (8 points) Write a spec CAnd such that, if s1 and s2 are specs, then new CAnd(s1, s2) returns true if and only if both s1 and s2 return true. For example, new CAnd(new BMinus(), new CMinusGpa()) returns true if and only if the transcript includes at least a B- in CS 121 and has an average GPA of C- or better.

Answer:

```
class CAnd implements Spec {
  Spec left, right;
  CAnd(Spec left, Spec right) { this.left = left; this.right = right; }
  boolean check(Map<Integer, Double> t) { return left.check(t) && right.check(t); }
}
```

d. (6 points) Suppose that we similarly have written classes CNot and COr, such that new CNot(s) returns the negation of spec s, and new COr(s1, s2) returns the disjunction of specs s1 and s2. Writing all those news is annoying. Write a class S with methods Spec not(Spec s), Spec and(Spec s1, s2), and Spec or(Spec s1, s2) such that calling S.not(s) returns the negation of s and analogously for the other methods.

Answer:

```
class S {
   static not(Spec s) { return new CNot(s); }
   static and(Spec s1, Spec s2) { return new CAnd(s1, s2); }
   static or(Spec s1, Spec s2) { return new COr(s1, s2); }
}
```

e. (4 points) Class S from part d is an example of what other design pattern that we saw in class? Explain your answer briefly.

Answer: Class S is an example of the factory pattern, in which a method is called to create a new object and return it.

Question 4. Graphs and Iterators (30 points). Recall the ListGraph class from Project 1:

```
public class ListGraph implements Graph {
    private HashMap<String, LinkedList<String>> nodes = new HashMap<>();
    public List<String> succ(String n) { ... }
    public List<String> pred(String n) { ... }
    ...
}
```

a. (4 points) Write a method Iterator<String> iterator() that returns an iterator over all nodes of the ListGraph. Below is the Iterator interface, for reference. *Hint: You may want to use the method Set<K> keySet() of HashMap. A Set is a standard Java Collection, with the usual methods; as such, you can assume there exist any typical methods that would exist for a Set or a Collection.*

```
interface Iterator<E> {
  boolean hasNext();
  E next();
}
```

Answer:

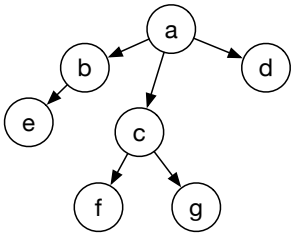
```
Iterator<String> iterator() { return nodes.keySet().iterator(); }
```

b. (6 points) Write a method List<String> roots() that returns a list of the *roots* of the graph, i.e., all nodes that have no predecessor.

Answer:

```
List<String> roots() {
  List<String> result = new LinkedList<>();
  for (String n : nodes.keySet()) { if (pred(n).isEmpty()) { result.add(n); } }
  return result;
}
```

c. (10 points) Write a method Iterator<String> bfs() that returns an Iterator whose next method returns all the nodes in the graph in *breadth-first search order*. (You also need to define the hasNext method.) This means after a node is visited, its children are visited next, then its childrens' children, etc. For example, for the following graph, the nodes are visited in alphabetical order (a, b, c, ...).



Hints:

- Your Iterator should maintain a List of nodes to visit next.
- Initially, the list contains the roots of the graph (call roots from part b). There is no specified ordering among the roots.
- The next node to visit is the first element of the list (which could be retrieved with remove(0)).
- After visiting a node, add its children to the *end* of the list (with add(E) or addAll(List<E>)). The children may be added in any order.
- You may assume there are no cycles in the graph, and your iterator may visit the same node multiple times if there are multiple paths to a node from a root.

Answer:

```
class BfsIterator implements Iterator<String> {
  List<String> toVisit = new LinkedList<>();
  BfsIterator () { toVisit.addAll(roots()); }
  boolean hasNext() {
    return !toVisit.isEmpty();
  }
  String next() {
    String res = toVisit.remove(0);
    toVisit.addAll(succ(res));
    return res;
  }
}
Iterator<String> bfs() { return new BfsIterator(); }
```

d. (10 points) Write a method Iterator<String> bfs(List<ListGraph> gs) that returns an Iterator that visits all the nodes of all of the graphs in gs in breadth-first order, as follows:

- The graphs in gs should be visited from first to last, in order.
- Use an iterator to keep track of where you are among the list of graphs.
- Use bfs from part c to visit the nodes of each individual graph.
- When next is called, there are two cases: Either get the next node from the current graph; or iterate to the next graph and get its first node.
- The logic for hasNext is similar.
- You may assume all of the graphs include at least one node.

Answer:

```
class BfsGsIterator implements Iterator<String> {
  Iterator <ListGraph> toVisit;
  Iterator <String> cur;
  BfsIterator ( List <ListGraph> gs) { toVisit = gs. iterator (); cur = toVisit .next (). bfs (); }
 boolean hasNext() {
   return cur.hasNext() || toVisit .hasNext();
 }
 String next() {
   if (!cur.hasNext()) { cur = toVisit .next (). bfs (); }
   return cur.next ();
 }
}
Iterator <String> bfs(List<ListGraph> gs) { return new BfsGsIterator(gs); }
```