Autumn CS193D Final Solution

Problem 1: All About Talk Shows

Inspect the following nonsense code where all implementations have been `inlined` for convenience (assume all methods are `public` and all instance methods are `const`):

```
class montel {
   static void jenny() { cout << "montel::jenny" << endl; }
   virtual void oprah() = 0;
   virtual void ricki() { cout << "montel::ricki" << endl; jenny(); }
   void rosie() { cout << "montel::rosie" << endl; ricki(); }
   virtual void sally() = 0;
};

class jerry : public montel {
   static void jenny() { cout << "jerry::jenny" << endl; }
   virtual void oprah() { cout << "jerry::oprah" << endl;}
   virtual void ricki() { cout << "jerry::ricki" << endl; sally(); }
};

class conan : public jerry {
   void rosie() { cout << "conan::rosie" << endl; jenny(); }
   virtual void sally() { cout << "conan::sally" << endl; rosie(); }
};

class dave : public montel {
   static void jenny() { cout << "dave::jenny" << endl; }
   virtual void oprah() { cout << "dave::oprah" << endl; }
   virtual void ricki() { cout << "dave::ricki" << endl;
                          montel::ricki(); }
   virtual void sally() { cout << "dave::sally" << endl; }
};
```

The `gossip` function is designed to take a `const montel` reference as its only parameter:

```
static void gossip(const montel& host)
{
   host.rosie();
}
```

What are the possible types that `host` may be referencing at runtime? For each possibility, trace through a call to `gossip` and present its output.

> The `montel` class can't be instantiated, because it leaves `oprah` and `sally` as pure `virtual`. The `jerry` class can't be instantiated either—even though it does provide a concrete implementation for `oprah`, it fails to mention anything about a `sally` method and therefore inherits the pure virtual `sally` from `montel`. Both dave and conan clear all pure virtuals, so they are concrete classes and can be instantiated without any problem.

Assuming that `host` refers to a `dave` instance, the output would be:

```
montel::rosie
dave::ricki
montel::ricki
montel::jenny
```

If host instead refers to a conan instance, the output would be:

```
montel::rosie
jerry::ricki
conan::sally
conan::rosie
jerry::jenny
```

Problem 2: Stanford Students

Students are classified as either Workaholics, PartyAnimals, and Introverts. Each student has a list of friends (who are other students) and tracks two quantities: the amount of work a student has to do for his classes and his sleep deficit, both expressed as an integer number of hours. The list of friends is maintained using the STL `vector` class you've come to know and love; note that a student's friends are not necessarily of the same type: Workaholics are friends with PartyAnimals and Introverts as well as other Workholics.

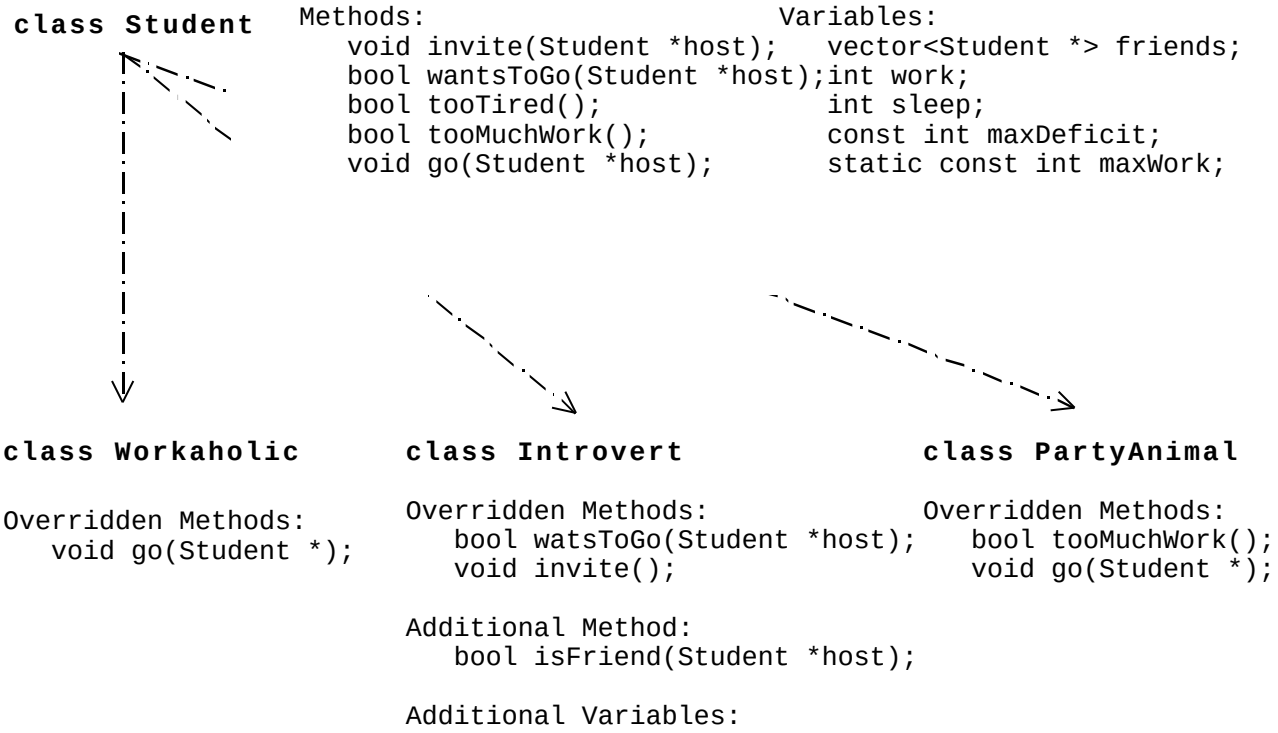
We're interested in what happens when you try to invite a student to a party by sending an `invite(Student *host)` message to a Student object. The host parameter is another Student who is extending the party invitation.

First off, all Students have a threshold on the maximum sleep deficit. For Workaholics, the threshold is 6, for PartyAnimals it is 12, for Introverts it is 4. If a Student's sleep deficit is above his threshold, he won't go to the party. Also if a student has too much work to do (over 10 hours), they won't go the party—except of course for PartyAnimals who never skip a party because of any work they have to do. Introverted folks don't often go to parties, even if they're all caught up on their work and sleep. However, on every 10th invitation they receive, if they meet the usual sleep and work criteria and the host of the party is one of their friends, they will go to the party.

If a Student decides to accept the invitation, then he goes to the party. Going to the party increases a Student's sleep deficit by 2 hours since they stay out late. When a Workaholic comes home from a party, he stays up even later to do some work, so his sleep deficit goes up another 3 hours, but his work goes down by 3 hours. When a PartyAnimal goes to a party, he invites all of his friends to come with him (making it clear who the real host of the part is.)

We recommend thinking through the entire design before making any decisions.

Just like you did for cacti, draw a little tree modeling the student class hierarchy. List the instance variables and methods (including their types / prototypes) for each class. This drawing will serve as your .h file, so include all the necessary type information and method headers. You will not need to mention or define constructors or other setup code at all—just assume that a miracle occurs and your objects are all set up at run time. You do not need to deal with `virtual`, `private`, `public`, or `protected` specifiers.



Understand that there were several acceptable designs. We were looking for an intelligent design that clearly attempted to factor as much generic behavior and functionality to the `Student` base class as possible. The actual interpretation of what a friend was, whether or not the incoming invitation was the 10th before or after the modulo 10 check… none of that really matters, provided the inheritance hierarchy wasn't affected in any interesting way.

Provide implementation code for the `invite` methods of all `Students` along with any necessary helper methods. You have this and the next two pages to do this. Make sure you are happy with your class hierarchy before you do this. (Don't worry about any infinite recursion resulting from friends inviting friends inviting friends inviting friends and any invitation cycles that result.)

```
/*
 * Class Student Functionality
 * ---------------------------
 */

void Student::invite(Student *host)
{
   if (wantsToGo(host))
      go(host);
}

void Student::go(Student *host) // host generally doesn't matter
{
   sleepDeficit += 2;
}

bool Student::wantsToGo(Student *host) // host ignored
{
   return (!tooMuchWork() && !tooTired());
}

bool Student::tooTired()
{
   return (sleep > maxDeficit);
   // assume maxDeficit set correctly in constructor
   // for each type of student
}

bool Student::tooMuchWork()
{
   return (work > maxWork);
}


/*
 * Class Workaholic Functionality
 * ------------------------------
 * Overrides only the go method.
 */

void Workaholic::go(Student *host)
{
   Student::go(host);      // go party as normal, but
   sleep += 3;             // stay up and do more work
   work -= 3;
}
```

```
/*
 * Class Introvert Functionality
 * -----------------------------
 */

bool Introvert::wantsToGo(Student *host)
{
   return (Student::wantsToGo(host) &&  // pass either host or NULL.. =)
           isFriend(host) &&
           (numInvites % 10 == 0));
}

void Introvert::invite(Student *host)
{
   Student::invite(host);
   numInvites++;           //  increment here to count all invites
}

bool Introvert::isFriend(Student *host)
{
   for (int i = 0; i < friends.size(); i++)
      if (friends[i] == host)
         return true;

   return false;
}

/*
 * Class PartyAnimal Functionality
 * -------------------------------
 */

bool PartyAnimal::tooMuchWork()
{
   return false;     // we *never* have too much work; rock on
}

void PartyAnimal::go(Student *host)
{
   for (int i = 0; i < friends.length(); i++)  // invite friends, too!
      friends[i]->invite(host);

   Student::go();    // then go to party normally
}
```

Problem 3: Defining your own RandomizedIterator

For this problem, you are going to design and implement your own iterator class—specifically, the `RandomizedIterator`. Traditional iterators normally reference an element within a container, and in response to `operator++`, advance to the next element in sequence. Your `RandomizedIterator`, given a range of elements, will traverse through the range in what appears to be a random order. Rather than advance to the next element in the sequence, `operator++` will update a `RandomizedIterator` to reference any one of the elements not previously referenced. Additional applications of `operator++` will continue to access previously unseen elements. If all elements have been referenced, `operator++` will advance to the past-the-end state.

For example, the following program would print out the first 10 prime numbers in increasing order:

```
int main()
{
   int primes[] = {2, 3, 5, 7, 11, 13, 17, 19, 23, 29};
   int *start = primes;
   int *end = primes + 10;
   while (start != end) {
      cout << *start << endl;
      ++start;
   }
}
```

Should we want to produce a permutation of the first 10 primes, we could leverage the behavior of our `RandomizedIterator` to write the following:

```
int main()
{
   int primes[] = {2, 3, 5, 7, 11, 13, 17, 19, 23, 29};
   RandomizedIterator<int *> start(primes, primes + 10);
   RandomizedIterator<int *> end;
   while (start != end) {              // calls operator!=
      cout << *start << endl;          // calls operator*
      ++start;                         // calls prefix operator++
   }
}
```

The output of the above program would vary from run to run, but each would list the 10 primes in any one of the 10! possible orderings.

The RandomizedIterator need not traverse over every single element in the range. The following program prints out 6 lottery numbers from a range of 1 to 40:

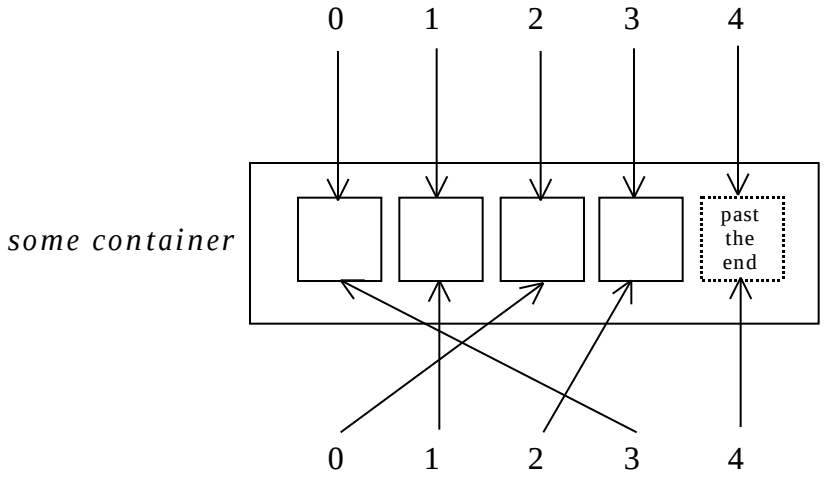
```
int main()
{
   vector<int> countingSet(40);

   for (int i = 0; i < 40; i++)
      countingSet[i] = i + 1;

   RandomizedIterator<vector<int>::iterator> generator(countingSet.begin(),
                                                       countingSet.end());
   cout << "Today's lottery numbers are:"
   for (int j = 0; j < 6; i++) {
      cout << '\t' << *generator++ << endl;
   }
}
```

Note that `generator` sees the full spectrum of possibilities, any subset of 6 numbers could be generated in any order whatsoever, all with equal probability.

The `start` and `end` iterators passed to `RandomizedIterator`'s constructor would access elements in this order.



The order in which the elements of a `RandomizedIterator` **might** access the elements, provided the same `start` and `end` are passed to its constructor.

Presented here is the public interface for the `RandomizedIterator` template class you are expected to design (by specifying all the `private` implementation data you need to support these operations) and implement (within the function and method stubs provided over the next few pages.) You are responsible for `everything`, and the strength of your design is just as important as the correctness of your code. Bottom line: you must ensure that your iterator behaves as any built-in iterator would.

Your implementation will benefit from the use of the `random_shuffle` algorithm, which takes a range of elements, bracketed by two iterators (just as `for_each` does, for example), and shuffles the elements, leaving them in one of the n! different possible permutations.

```
template <class BidirectionalIterator>
void random_shuffle(BidirectionalIterator start, BidirectionalIterator end);

template <class BidirectionalIterator>
class RandomizedIterator {

   typedef iterator_traits<BidirectionalIterator>::value_type
         value_type;

   friend bool operator==(const RandomizedIterator<BidirectionalIterator>& lhs,
                          const RandomizedIterator<BidirectionalIterator>& rhs);
   friend bool operator!=(const RandomizedIterator<BidirectionalIterator>& lhs,
                          const RandomizedIterator<BidirectionalIterator>& rhs);

   public:
      RandomizedIterator(BidirectionalIterator start,
                         BidirectionalIterator end);
      RandomizedIterator();

      const value_type& operator*() const;
      value_type& operator*();
      const RandomizedIterator& operator++();
      const RandomizedIterator operator++(int);

   private:
      vector<BidirectionalIterator> iterators;
      vector<BidirectionalIterator>::iterator curr;

};
```

specify all of your fields here, using whatever is necessary

Iterators will actually store all of the Bidirectionalterators in between the start and end values passed to a constructor, and curr will actually point to the BidiectionalIterator currently being treated. The constructor initializes the iterators array and shuffles it to generate a random permutation. operator++ can then just advance curr like a normal iterator and know it's arriving at something that hasn't been seen before.

Provide implementations for all of the functions and methods, making sure that the suite of operations that result make your `RandomizedIterator` class compatible with all of the STL algorithms we've discussed in lecture, including `for_each` and `accumulate`. In short, your resultant class should be a proper iterator.

```
/*
 * Constructor: RandomizedIterator(start, end)
 * -------------------------------------------
 * Constructs an instance of a RandomizedIterator, where the
 * RandomizedIterator knows to traverse over elements in the range
 * [start, end).  The RandomizedIterator, rather than iterating over
 * the elements sequentially, seemingly iterates over the elements
 * of the range in a random order, making a point to never revisit
 * a previously visited element, and visit every element once.  When
 * all elements have been accessed, the RandomizedIterator will, in the
 * operator== sense, be equal to the past-the-end RandomizedIterator
 * returned by the zero-argument constructor.
 */

template <class BidirectionalIterator>
RandomizedIterator<BidirectionalIterator>::
RandomizedIterator(BidirectionalIterator start, BidirectionalIterator end)
{
   while (start != end) {
      iterators.push_back(start),
      ++start;
   }

   random_shuffle(iterators.begin(), iterators.end());
   curr = iterators.begin();
}

/*
 * Constructor: RandomizedIterator()
 * ---------------------------------
 * Constructs an instance of the part-the-end RandomizedIterator,
 * an iterator which represents the situation where no remaining
 * elements may be legally accessed.
 */

template <class BidirectionalIterator>
RandomizedIterator<BidirectionalIterator>::RandomizedIterator()
{
   curr = iterators.end();
}
```

```
/*
    * Dereference operators: const and non-const forms
    * ------------------------------------------------
    * Returns a reference (either const or non-const) to the
    * client element that the RandomizedIterator is currently
    * pointing to.  Note that a BidirectionIterator isn't what
    * gets returned, but instead a reference to one of the elements
    * pointed to by one of the original BidirectionalIterators.
    */

   template <class BidirectionalIterator>
   const typename RandomizedIterator<BidirectionalIterator>::value_type&
   RandomizedIterator<BidirectionalIterator>::operator*() const
   {
      return **curr;
   }


   template <class BidirectionalIterator>
   typename RandomizedIterator<BidirectionalIterator>::value_type&
   RandomizedIterator<BidirectionalIterator>::operator*()
   {
      return **curr;
   }

   /*
    * Increment operators: both pre and post-fix forms
    * ------------------------------------------------
    * Advances the RandomizedIterator to some other element
    * of the original sequence, that has not been visited
    * previously.  If the RandomizedIterator has previously
    * references all other elements in the sequence, then
    * it should advance to a state such that future calls
    * to operator++ are ignored and such that it compares
    * (in an operator== sense) equally to any past-the-end
    * iterator returned by the zero-arg constructor.
    */

   template <class BidirectionalIterator>
   const RandomizedIterator<BidirectionalIterator>&
   RandomizedIterator<BidirectionalIterator>::operator++()
   {
      if (curr != iterators.end())
         curr++;
      return *this;
   }

   template <class BidirectionalIterator>
   const RandomizedIterator<BidirectionalIterator>
   RandomizedIterator<BidirectionalIterator>::operator++(int)
   {
      RandomizedizedIterator<BidirectionalIterator> old(*this);
      operator++();
      return old;
   }
```