Anagram: Using Normalizers

- How can we normalize an Anaword object differently?
  - Call normalize explicitly on all Anaword objects
  - Have Anaword objects normalize themselves
  - Advantages? Disadvantages?

- If Anaword objects normalize themselves, how can we experiment with different normalization techniques?
  - What about `cp anaword.cpp oldanaword.cpp`?
  - What about deciding at runtime on normalization?

- We need inheritance!
How to normalize?

Where should the code for normalizing Anaword objects live?
1. Where it’s needed.
2. In a separate function
3. In a separate function inside of the Anaword class
4. In its own class

Why?
Pointer questions

- In which location do dynamic variables reside?
  1. The code segment.
  2. The data segment.
  3. The heap.
  4. The run-time stack.
Consider the following statements

```c
int *p;
int l;
int k;
l = 42;
k = l;
p = &i
```
Pointer Question #2

Consider the following code fragment:
```c
int *p;
int i;
int k;
l = 42;
k = i;
p = &i
```

After these statements, which of the following statements will change the value of i to 75?

1. `k = 75;`
2. `*k = 75;`
3. `p = 75;`
4. `*p = 75;`
5. Two or more of the answers will change i to 75.

Why should your code NEVER look like this?
Normalizer hierarchy

- Anaword objects normalize themselves
  - Where does the normalizer come from?
    - Passed in at construction time
    - Obtained from normalizer factory
    - Other approaches?

- How is Normalizer used?

- Normalizer is conceptually an interface
  - Different implementations of the interface have different behavior (guts) but same skin (sort of)
Benefits of inheritance, interfaces

- Suppose you learn about a new class WebStream that conforms to the input stream interface (cin, ifstream, ...)
  - Read words, lines, chars from a web page?

```cpp
void readWords(istream& input) {
    string s, line;
    char ch;
    getline(input, line);
    input >> s;
    input.get(ch);
}
```

- We can pass cin, ifstream, WebStream, etc. to readWords
  - Why is this an advantage?
  - Inheritance and late/dynamic binding
Why inheritance?

Add new shapes easily without changing much code
- Shape * s1 = new Circle();
- Shape * s2 = new Square();

abstract base class:
- interface or abstraction
- pure virtual function

crrocess subclass
- implementation
- provide a version of all pure functions

“is-a” view of inheritance
- Substitutable for, usable in all cases as-a

User’s eye view: think and program with abstractions, realize different, but conforming implementations,

don’t commit to something concrete until as late as possible
Example of inheritance

- What is behavior of a shape?

```cpp
void doShape(Shape * s) {
    cout << s->area() << endl;
    cout << s->perimeter() << end;
    s->expand(2.0);
    cout << s->area() << endl;
    cout << s->perimeter() << endl;
}

Shape * s1 = new Circle(2);
Shape * s2 = new Square(4);
Shape * s3 = new Rectangle(2,5);
doShape(s1); doShape(s2); doShape(s3);
```
Inheritance (language independent)

- **First view: exploit common interfaces in programming**
  - Streams in C++, iterators in Tapestry classes
    - Iterators in STL/C++ share interface by convention/templates
  - Implementation varies while interface stays the same

- **Second view: share code, factor code into parent class**
  - Code in parent class shared by subclasses
  - Subclasses can *override* inherited method
    - Can subclasses override and call?

- **Polymorphism/late(runtime) binding (compare: static)**
  - Actual function called determined when program runs, not when program is compiled
Inheritance Heuristics

- A base/parent class is an interface
  - Subclasses implement the interface
    - Behavior changes in subclasses, but there’s commonality
  - The base/parent class can supply some default behavior
    - Derived classes can use, override, both

- Push common behavior as high up as possible in an inheritance hierarchy

- If the subclasses aren’t used polymorphically (e.g., through a pointer to the base class) then the inheritance hierarchy is probably flawed
Normalizer details (see Anaword)

- What’s static? Why private? Static initialization?

class Anaword
{
  public:
    // not shown
  private:
    void normalize();
    static Normalizer * ourNormalizer;
};

void Anaword::normalize()
// postcondition: mySortedWord is sorted version of myWord
{
  if (ourNormalizer == 0) {
    ourNormalizer = NormFactory::getNormalizer();
  }
  myNormalizedWord = ourNormalizer->normalize(myWord);
}
Guidelines for using inheritance

- Create a base/super/parent class that specifies the behavior that will be implemented in subclasses
  - Most/All functions in base class may be virtual
    - Often pure virtual (= 0 syntax), subclasses must implement
  - Subclasses do not need to specify virtual, but good idea
    - May subclass further, show programmer what’s going on
  - Subclasses specify inheritance using : public Base
    - C++ has other kinds of inheritance, stay away from these
  - Must have virtual destructor in base class

- Inheritance models “is-a” relationship, a subclass is-a parent-class, can be used-as-a, is substitutable-for
  - Standard examples include animals and shapes
Inheritance guidelines/examples

- Virtual function binding is determined at run-time
  - Non-virtual function binding (which one is called) determined at compile time
  - Need compile-time, or late, or polymorphic binding
  - Small overhead for using virtual functions in terms of speed, design flexibility replaces need for speed
    - Contrast Java, all functions “virtual” by default
- In a base class, make all functions virtual
  - Allow design flexibility, if you need speed you’re wrong, or do it later
- In C++, inheritance works only through pointer or reference
  - If a copy is made, all bets are off, need the “real” object
class Student
{
    public:
        Student(const std::string & name);
        virtual ~Student();

        virtual void eat();
        virtual void work();
        virtual void sleep();
        virtual void live();

        bool isAlive() const;
    // more here
Implementation of behavior, .cpp file

```cpp
void Student::sleep()
{
    myEnergy += 10;
    cout << "Zzzzzzzzzzzzzzz, resting sleep" << endl;
}

void Student::live()
{
    eat();
    work();
    sleep();
}
```
See students.cpp, school.cpp

- **Base class student doesn’t have all functions virtual**
  - What if subclass has different `name()` function?
    - `name()` bound at compile time, no change observed

- **How do subclass objects call parent class code, see DukeStudent class in school.cpp**
  - `class::function` syntax, must know name of parent class

- **Why is base class data protected rather than private?**
  - Must be accessed directly in subclasses, why?
  - Not ideal, try to avoid state in base/parent class: trouble
    - What if derived class doesn’t need data?
Inheritance Heuristics in C++

- **Pure virtual (aka abstract) function makes a class abstract**
  - Cannot be instantiated, but can be constructed (why?)
    - What do subclasses do?
  - Default in C++ is non-virtual or *monomorphic*
    - Unreasonable emphasis on efficiency, sacrifices generality
    - If you think subclassing will occur, all methods are virtual
  - Must have virtual destructor, the base class destructor (and constructor) will be called

- **We use public inheritance, models *is-a* relationship**
  - Private inheritance means is-implemented-in-terms-of
    - Implementation technique, not design technique
    - Not ubiquitous in other languages
Difference in behavior?

- What’s a field and what’s a method?
  - # tires on car?
  - # doors on car?
  - How student lives?

- Where does name of school belong? What about energy increment?

- What’s problem with hierarchy here?
  - NCState student?
Problems with inheritance

- Consider the student example and burrito eating
  - CosmicStudent is a subclass of DukeStudent
    - What behavior changes in the new subclass?
  - What about a UNCStudent eating cosmic cantina food?
    - Can we have CosmicDukeStudent and CosmicUNCStudent?
    - Problems with this approach?

- Alternative to inheritance: use delegation (aka layering, composition)
  - Just like myEnergy is a state variable with different values, make myEater a state variable with different values
  - Delegate behavior to another object rather than implementing it directly
Delegation with school/student

If there's a class Eater, then what instance variable/field will a Student store to which eating behavior delegated?

```cpp
void Student::eat()
{
    myEater->doEat();
}
```

- How is the eater instance variable initialized?
- Could we adopt this approach for studying too?
- When is this approach better/worse?
Problem Solving

- Some believe that being a good programmer will be a prerequisite for being a good mathematician
  - Computer-aided proofs are big (four color theorem, Kepler’s conjecture)
  - Computer programs are very formally complete and precise
- Teachers often speak of a magical “problem solving intuition”
- Does such a thing exist?
- Is it really just experience and pattern recognition?
- What are some tools to help learning programmers to solve problems?
Dropping Glass Balls

- Tower with N Floors
- Given 2 glass balls
- Want to determine the lowest floor from which a ball can be dropped and will break
- How?

- What is the most efficient algorithm?
- How many drops will it take for such an algorithm (as a function of N)?
Pairing-up students

- Assume you have $n$ students ($n$ is even)
- You would like to have lab sections in which every student has a partner to work with for that particular lab section
- As there are $n$ students, this can be done in $n-1$ days optimally
- How?
- Dead-end solution with 6 people
  - Day 1: [1 pairs with 2] [3 pairs with 4] [5 pairs with 6]
  - Day 2: [1 pairs with 3] [2 pairs with 4] ... uh oh