Course Topics

- **Design concepts**
  - A bit more C++
  - *Complexity*
- **Data Structures**
  - Sets
  - Trees
  - Maps
- **Algorithms**
  - Sorting
  - Game playing
  - Inheritance
  - Linked lists
  - Tries
  - Graphs
  - Searching
Course Overview

- **Lectures, Recitations, Quizzes, Programs, Assignments**
  - Recitation based on questions given out in previous week
    - Discuss answers, answer new questions, small quiz
    - More opportunities for questions to be answered.
  - Lectures based on readings, questions, programs
    - Online quizzes used to motivate/ensure reading
    - In-class questions used to ensure understanding
  - Programs
    - Theory and practice of data structures and OO programming
    - Fun, practical, tiring, …
    - Weekly programs and longer programs
  - Assignments
    - Written, test knowledge of efficiency & data structures
    - Good practice for exams
  - 2 tests & final
Frequently Asked Questions

● What is the prerequisite? (choose one)
  ➢ CPS 6
  ➢ 4 or 5 on AP Computer Science AB exam
  ➢ Instructor’s permission

● How does this course fit into the curricula?
  ➢ Required for majors & minors
  ➢ Solid grounding in programming, data structures, and algorithms
  ➢ *It’s the foundation of your whole computer science education.*

● How do keep up to date?
  ➢ Read web page *regularly*
    http://www.cs.duke.edu/courses/fall03/cps100
  ➢ Read discussion forum *regularly*
  ➢ Read your email
On the subject of questions…

- Did you ask any good questions today?
  - *Ideas and Information* by Nobel prize winning physicist Arno Penzias
  - Questions which illuminate help nourish ideas
  - Children are born curious
  - Fear of public displays of ignorance prevents learning
- Participate in class
- Go to office hours
- Make study groups with your classmates
In class, we will use the Personal Response System (PRS)
- Pick up your receiver every day before class
- ConcepTest: multiple choice questions that highlight an important concept gleaned from the lecture and/or reading
  - *It’s OK not to know!*
- Peer instruction: after seeing the results, you will have confer with your neighbor and revote

Just in Time Teaching
- Discuss your assignment responses in class

Why respond?
- Counts toward inclass work score
- Effort, participation, and altruism
- Makes class better!
Efficient Programming

- Designing and building efficient programs efficiently requires knowledge and practice
  - Hopefully the programming language helps, it’s not intended to get in the way
  - Object-oriented concepts, and more general programming concepts help in developing programs
  - Knowledge of data structures and algorithms helps

- Tools of the engineer/scientist/programmer/designer
  - A library or toolkit is essential, STL or wheel re-invention?
  - Programming: art, science, engineering? None or All?
  - Mathematics is a tool
  - Design Patterns are a tool
Why is programming fun?

What delights may its practitioner expect as a reward?

First is the sheer joy of making things

Second is the pleasure of making things that are useful

Third is the fascination of fashioning complex puzzle-like objects of interlocking moving parts

Fourth is the joy of always learning

Finally, there is the delight of working in such a tractable medium. The programmer, like the poet, works only slightly removed from pure thought-stuff.

Fred Brooks
Tradeoffs

- This course is about all kinds of tradeoffs: programming, structural, algorithmic
  - Programming: simple, elegant, quick to run/to program
    - Tension between simplicity and elegance?
  - Structural: how to structure data for efficiency
    - What issues in efficiency? Time, space, programmer-time
  - Algorithmic: similar to structural issues

- How do we decide which choice to make, what tradeoffs are important?
See readwords.cpp

- This reads words, how can we count different/unique words?

tvector<string> list;
string filename, word;
cin >> filename;
ifstream input(filename.c_str());
CTimer timer;
timer.Start();
while (input >> word) {
    list.push_back(word);
}
timer.Stop();
cout << "read " << list.size() << " words in ";
cout << timer.ElapsedTime() << " seconds" << endl;
Tracking different/unique words

- We want to know how many times ‘the’ occurs
  - Do search engines do this? Does the number of occurrences of “basketball” on a page raise the priority of a webpage in some search engines?
    - Downside of this approach for search engines?

- Constraints on solving this problem
  - We must read every word in the file (or web page)
  - We must search to see if the word has been read before
  - We must process the word (bump a count, store the word)

  - Are there fundamental limits on any of these operations? *Where should we look for data structure and algorithmic improvements?*
Search: measuring performance

- How fast is fast enough?

```cpp
bool search(const tvector<string> & a, const string & key)
// pre:  a contains a.size() entries
// post: return true if and only if key found in a
{
    int k; int len = a.size();
    for(k=0; k < len; k++)
        if (a[k] == key) return true;
    return false;
}
```

- C++ details: parameters? Return values? Vectors?
- How do we measure performance of code? Of algorithm?
  - Does processor make a difference? P4, G5, ???
Tradeoffs in reading and counting

- Read words, then sort, determine # unique words?
  - frog, frog, frog, rat, tiger, tiger, tiger, tiger

- If we look up words as we're reading them and bump a counter if we find the word, is this slower than previous idea?
  - How do we look up word, how do we add word

- Are there kinds of data that make one approach preferable?
  - What is best case, worst case, average case?

- What's one function spec & implementation to count # unique words in a list/vector of words
  - See readwords3.cpp
Review/Preview: Anagrams/Jumbles

- Brute-force approach to finding anagrams/solving Jumbles
  - Brute-force often thought of as “lack of thought”
  - What if the better way requires too much thought?
  - What if there’s nothing better?
- nelir, nelri, neirl, neirl, nerl, nleir, nleri, nlier, nlire, nlrei, nlrie, nler, nierl, niler, nilre, nirel, … lenir, lenri, leirn, leirn, lerni, lerin, liner
  - What’s the problem here?
  - Is there a better method?
Brute force? permana.cpp

// find anagram of word in wordSource
// list is a vector [0, 1, 2, ..., n]
Permuter p(list);
int count = 0;
string copy(word);// makes copy the right length

for(p.Init(); p.HasMore(); p.Next()) {
    p.Current(list);
    for(k=0; k < list.size(); k++) {
        copy[k] = word[list[k]];
    }
    if (wordSource.contains(copy)) {
        cout << "anagram of " << copy << endl;
        break; // find first anagram only
    }
}
Quantifying brute force for anagrams

- On one machine make/test a word takes $10^{-5}$ seconds/word
  - 9! is 362,880: how long does this take?
  - What about a ten-letter word?

- We’re willing to do some pre-processing to make the time to find anagrams quicker
  - Often find that some initialization/up-front time or cost saves in the long run
  - We need a better method than trying all possible permutations
  - What properties do words share that are anagrams?
Toward a faster anagram finder

- Words that are anagrams have the same letters; use a letter fingerprint or signature/histogram to help find anagrams
  - Count how many times each letter occurs:
    - “teacher” 1 0 1 0 2 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0
    - “cheater” 1 0 1 0 2 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0

- Store words, but use fingerprint for comparison when searching for an anagram
  - How to compare fingerprints using operator ==
  - How to compare fingerprints using operator <

- How do we make client programmers unaware of fingerprints? Should we do this?
Another anagram method

- Instead of fingerprint/histogram idea, use sorted form of word
  - “gable” and “bagel” both yield “abegl”
  - Anagrams share same sorted form

- Similarities/differences to histogram/fingerprint idea?
  - Both use canonical or normal/normalized form
  - Normalized form used for comparison, not for printing
  - When should this normal form be created?

- When is one method preferred over the other?
  - Big words, little words? Different alphabets? DNA vs English?
OO and C++ features we’ll use

- We’ll use an adapter or wrapper class called Anaword instead of a string
  - Clients can treat Anaword objects like strings, but the objects are better suited for finding anagrams than strings
  - The Anaword for “bear” prints as “bear” but compares to other Anaword objects as
    \[11001000000000000100000000\]

- C++ allows us to overload operators to help, not necessary but good cosmetically
  - Relational operators \(==\) and \(<\)
    - What about other operators: \(>\), \(<=\), \(>=\), and \(!=\)
  - Stream operator \(<<\)

- How should we implement overloaded operators?
Overloaded operators

- In C++ we can define what operator == and operator < mean for an object (and many other operators as well)
  - This is syntactically convenient when writing code
  - C++ details can be cumbersome (see Tapestry Howto E)

- In anaword.h there are four overloaded operators
  - What about > and >= ; what about != ; others?
  - What about printing, can we overload operator << ?
  - How do we access private data for printing? Comparing?

- Overloaded operators are not necessary, syntactic sugar.
Overloaded operators (continued)

- Typically operators need access to internal state of an object
  - Relational operators for Date, string, BigInt?
  - Where is “internal state”?

- For technical reasons sometimes operators should not be member functions:
  ```cpp
  BigInt b = enterBigValue();
  if (b < 2) ...
  if (2 > b) ...
  ```
  - We’d like to use both if statements, only the first can be implemented using `BigInt::operator <` (why?)

- Use helper member functions: equals, less, toString
  - Implement overloaded operators using helpers