Programming abstractly

Remember the purpose of the course

- Learn ideas in programming and system design that transcend any one language
- Learn that programming is not just coding
- Learn by doing

The most important idea

- Abstraction
  - “the act or process of separating in thought, of considering a thing independently of its associations; or a substance independently of its attributes; or an attribute or quality independently of the substance to which it belongs” (OED)
  - “leaving out of a number of resembling ideas what is peculiar to each” (attributed to Locke by Priestly, 1782)
  - Selective ignorance (A.R. Koenig, 1990’s)

Abstraction is selective ignorance

- When you drive a car, thinking about how the engine works is a distraction
- When you repair a car, thinking about how the engine works is essential
- Abstraction is deciding which aspects of a problem to consider and which ones to ignore

Kinds of abstraction

- Design
- Implementation
- Chunking

Design

- Design is mostly breaking large programs into smaller parts
- Crucial decisions include
  - where to draw the boundaries between the parts
  - how the parts should communicate
  - the interface(s) between the parts

What makes a good design

- It starts with a clear understanding of the problem
- Each component is well defined
- Each component has sensible, useful properties
- The components accurately model the problem

Design strategy

- Design is constructing a model
- A good model behaves similarly to what it models
- Therefore:
  - How our models behave is the most important thing about them
  - We should think about behavior before anything else

Design tactics

- What are the important pieces of our design?
- How do they behave? What operations do they support?
- Once we have decided on behavior, we can often begin writing code immediately

Class definitions as a design aid

- When you write down the public parts of a class definition, you are already part way toward your design
- You can compile the class before you fill in the details

Implementation abstraction

- Two forms
  - Conceptual abbreviations: subroutines, classes, templates, etc.
  - Chunking

An example of abstraction (in Awk)

```
{
    for (i = 1; i <= NF; ++i)
      ++words[$i]
}
END {
    for (s in words) {
        print words[s], s
    }
}
```

Why was this program easy?

- automatic input loop
- input broken into fields
- variable-length strings
- associative arrays
  - elements created automatically
  - easy iteration
- automatic memory management

A similar program in C++

```
#include <iostream>
#include <string>
#include <map>
int main() {
    std::map<string, int> words;
    std::string s;
    while (std::cin >> s) ++words[s];
    std::map<string, int>::iterator i;
    for (i = words.begin();
         i != words.end(); ++i)
       std::cout << i->second << “\t”
                 << i->first << std::endl;
}
```

Why was this program easy?

- easy to read a word at a time
- variable-length strings
- associative arrays
  - elements created automatically
  - easy iteration
- automatic memory management

Comparing C++ with Awk

- The Awk program is shorter
- An informal test shows that the Awk program is about twice as fast
- So why bother with the C++ version at all?

The real difference

- Awk was designed to solve this kind of problem
- C++ was designed to make it easy to implement libraries for a wide variety of problems
- The standard library doesn’t have particular applications in mind

What about performance?

- Awk has a built-in operation to read a line and break it into fields
- This operation is carefully optimized, because it is so common
- The C++ version spends most of its time reading input
- Writing a high-performance “Awk input” abstraction might pay off

Possible conclusions

- If you have a language that is intended to solve your specific problem, use it
- Otherwise, a language that supports a range of abstractions is useful—if you use it that way

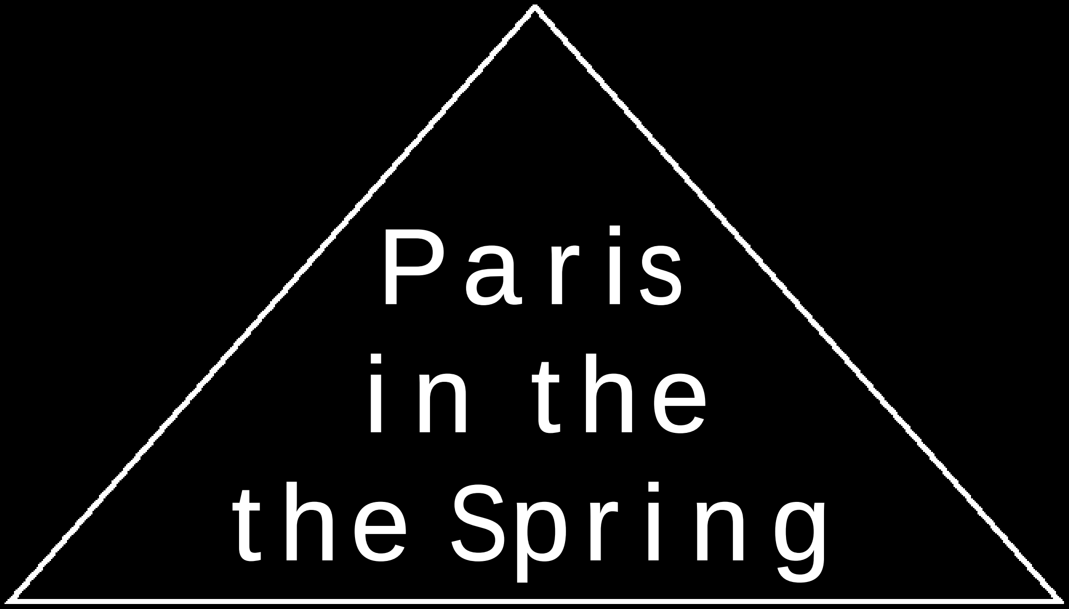
Abstraction and chunking

- The main part of design is creating suitable high-level abstractions
- The main part of programming is creating suitable low-level abstractions and chunks

Chunking

- We read text in words and phrases, not letters
- Similarly, we group together visual patterns that recur in programs (Example: `*p++ = *q++`)
- Finding useful chunks makes programs easier to understand, even when all the details are still right out in the open

An example of chunking



Paris
in the
the Spring

What did the text say?

The point of chunking

- We see what we expect to see
- Therefore, if we wish to be clear, we should write what people expect to see
  - which means we need to know (or influence) what people will expect
  - which probably requires a community

Another example of chunking

```
char* strcpy(char* p, const char* q) {
    while (true) {
        *p = *q;
        if (*q == ‘\0’)
            return;
        ++p; ++q;
    }
}
char* strcpy(char* p, const char* q) {
    while (*p++ = *q++) ;
}
```

Object-oriented programming

- An object has a *type*, a *state*, and a *behavior* (or behaviors)
- Sometimes we care about these properties, sometimes not
- An object-oriented language will make it easy to support objects to different degrees of abstraction

Why is OOP useful?

- Programming objects are useful abstractions of physical objects
- Even programs that do not deal with physical objects often want to offer behavior that models physical objects
- It is no surprise that OOP started out as a tool for writing simulation programs

OOP is not the world

- Pure FP (functional programming) is the opposite of pure OOP
  - In OOP, everything is data, even programs
  - In FP, everything is program, even data
- The resulting style is dramatically different

Generic programming

- A generic program is one that uses as little knowledge as possible about its surroundings
- Different languages express generic programs differently
  - Smalltalk uses generic typing
  - C++ uses templates
  - FP languages often support generic types

C++ templates

- Types that are dynamic during compilation and static during execution
- Often used to express containers and iterators
- Can be used as a way of connecting parts of a system

Memory management

- Some languages handle it automatically
- If you are using a language that doesn’t, you must make it part of your abstractions (handles, iterators, etc)
- C++ often makes it easy to do so
- Memory is not the only resource that programs must manage

Advice about programming

- Understanding the problem clearly is the hardest part of programming
- Making your design fit the your understanding is second hardest
- If you got both those parts right, implementation is usually easy
- So if your implementation goes to pieces, take another look at your design

Advice about languages

- Language and design usually depend on each other, at least a little
- Choice of language should depend on the whole context
  - what is available
  - local culture
  - what problems you want to solve
- Learn several languages—thoroughly

Meta-advice

Programming is a human activity; forget that and all is lost.