Designing and Using Classes

- **Class implementation, summary of what we've seen**
  - **Data is private and is accessible in each member function**
  - **Each object has it's own data, so that each of five Dice objects has its own `mySides` and `myRollCount`**
  - **Member function implementations are in a .cpp file, interface is in a .h file**

- **Compiling and linking, interface and implementation**
  - **Client programs #include a .h file, this is the interface**
  - **Client programs link the implementation, which is a compiled version of the .cpp file (.o or .obj suffix), implementations are often combined in a library, e.g., libtapestry, and the library is linked**

Implementing Classes

- **Determining what classes are needed, and how they should be implemented is difficult; designing functions is difficult**
  - **Experience is a good teacher, failure is a good teacher**

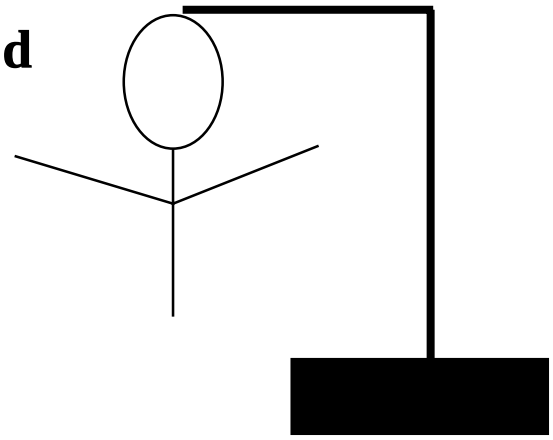
Good design comes from experience, experience comes from bad design

  - **Design and implementation combine into a cyclical process: design, implement, re-visit design, implement, test, redesign, …**
    - **Grow a working program, don't do it all at the same time**

- **One design methodology says "look for nouns, those are classes", and "look for verbs or scenarios, those are member functions"**
  - **Not every noun is a class, not every verb is a method**

Playing Hangman, toward a prototype

- **Hangman is a word game, a player tries to guess a secret word one letter at a time, each missed letter counts against the player, after 8 or 10 or 12 misses the player is "hung". Usually each miss results in drawing a body part on a gallows.**
  - **Diagram shows four misses**
  - **Part of 10-letter word is guessed**



- **What are nouns?**
- **What are verbs?**
- **What are scenarios?**

_ _ *t* _ _ *a* *t* _ _ _ a m o s n t

Nouns, scenarios, verbs

- **Get a word to guess**
  - **From another player, a dictionary, the web**
  - **From a *WordSource***
- **Show the word to the player, let the player guess letters**
  - **The word is displayed, then letters are revealed as guesses are made**
  - **Class *Word*, methods *Display*, *Reveal*, *Guess*, …**

- **Guess is also a noun, a letter is guessed, missed letters count against, good letters reveal, duplicate guesses don't count**
  - **GuessedLetters? Letters? Alphabet? Which is the noun?**

Implementing WordSource

- **What's the simplest way to get a word from a WordSource so that we can test the rest of the program**
  - **Can we design a class that's simple to test with at first, but easy to make more realistic later (essence of prototyping)**
  - **How can we guess pick one of several words at random once we're ready to move towards a more realistic implementation?**
    - **Alternatives using small number of strings and a Dice?**
    - **Alternatives using a file of words?**

- **What should we do to test the WordSource class?**
  - **Can we test without implementing the whole program?**
  - **Test each class separately when possible, isolate mistakes**

wordsource.h, wordsource.cpp

- *WordSource* will return a word, later add "from a file"

```
#include <string>
class WordSource
{
  public:
    WordSource();
    string GetWord();
};
```

```
// here's the .cpp file
#include "wordsource.h"
WordSource::WordSource()
{
}
string WordSource::GetWord()
{
    return "literature";
}
```

Guessing letters

- **Player guesses a letter, it's in the word, or a miss, or has been guessed already**
  - **Create a class *Letters*, have it report whether a letter has been guessed already, or a letter is in the word, or a miss**
  - **Should *Letters* report a miss/correct? If so, does Letters need to know the word? What are alternatives?**

- **Don't worry about implementation, worry about behavior, or the interface**
  - **Eventually you'll need to worry about implementing, what will be hardest/harder, how can we test without implementing hard part first?**

letters.h

- **We'll construct an instance of *Letters* from a secret word/string**
  - **Ask *Letters* to display the "to be guessed word"**
  - **Guess a letter, have *Letters* report if it's in the word**
  - **Optionally report duplicate guesses, add this later**

```
class Letters
{
  public:
    Letters(const string& s);
    bool GuessLetter(const string& letter);
    void Display();

  private:
    string myDisplay;  // show this string
    string myString;   // the secret word
};
```

Testing and implementing `letters.cpp`

- ***GuessLetter*** **uses `string::find` to determine miss/correct**
  - **Must also "save state" so that *Display* shows guesses (and later so that duplicate guess detection works)**
  - **Initially we can just return true/false to test, no state saved**

- **We'll test this version, but be thinking about what `Letters::GuessLetter` must do**
  - **Change state so that display shows guessed letters**
  - **Ultimately, remember guesses to not penalize twice**
  - **What about determining when game is over?**
  - **What about determining # misses so far? Who tracks?**

hang.cpp, the main/testing program

```
#include <string>
#include "prompt.h"
#include "letters.h"
#include "wordsource.h"

int main()
{   WordSource ws;
    string s = ws.GetWord();
    Letters letters(s);
    while (true)
    {  letters.Display();
       s = PromptString("guess a letter");
       if (letters.GuessLetter(s))
       {   cout << "that's in the word!!" << endl;
       }
       else
       {   cout << "that's a miss" << endl;
       }
    }
}
```

Programming Tips, Heuristics, Help

- **Develop a core working program, add to it slowly**
  - **Iterative enhancement, test as you go, debug as you go**
- **Do the hard part first, or do the easy part first**
  - **Which is best? It depends.**
- **Concentrate on behavior first when designing classes, then on state**
  - **State is useful for communicating between method calls**
- **If you're using several classes, you'll need to modify the Makefile or your project in an IDE: Codewarrior/Visual C++**

Common interfaces are a good thing

- The class WordStreamIterator iterates over a file returning one word/string at a time

```
string filename = PromptString("enter file name: ");
WordStreamIterator ws;
ws.Open(filename);
for(ws.Init(); ws.HasMore(); ws.Next())
{    cout << ws.Current() << endl;
}
```

- The class StringSet and StringSetIterator allow sets of strings to be iterated over one string at a time

```
StringSet sset;
sset.insert("banana");   sset.insert("cherry");
StringSetIterator it(sset);
for(it.Init(); it.HasMore(); it.Next())
{   cout << it.Current() << endl;
}
```

Reuse concepts as well as code

- **Using the same syntax for iterating saves time in learning about new classes, will save coding when we learn how to exploit the commonality**

- **We can develop different Question classes and "plug" them into a quiz program if the member functions have the same name**
  - **See *quiz.cpp*, *mathquest.cpp*, and *capquest.cpp***
  - **Programs must #include different headers, and link in different implementations, but quiz.cpp doesn't change**

- **Random walk classes: one- and two-dimensional, can use the same driver program if the classes use the same method names**

Random walks

- **Throwing darts (randomness in programs) is a technique for simulating events/phenomena that would be otherwise difficult**
  - **Molecular motion is too time-consuming to model exactly, use randomness to approximate behavior**
    - **Consider the number of molecules in 10^{-10} liters of a gas, each affects the other if we're simulating motion**
    - **6.023×10^{23} molecules/22.4 liters is (approx) 2.7e+12molecules**
  - **If we can do 100 megaflops, what does this mean?**
- **Simulations are important in many modelling applications, require pseudo-random numbers and some mathematics as well as programming**

Walking behavior (see frogwalk2.cpp)

```
int main()
{
    int numSteps = PromptRange("enter # steps",0,30000);
    RandomWalk frog(numSteps);       // define two random walkers
    RandomWalk toad(numSteps);
    int samePadCount = 0;            // # times at same location

    frog.Init();                     // initialize both walks
    toad.Init();
    while (frog.HasMore() && toad.HasMore())
    {   if (frog.Current() == toad.Current())
         {   samePadCount++;
        }
        frog.Next();
        toad.Next();
    }
     cout << "frog position = " << frog.Position() << endl;
     cout << "toad position = " << toad.Position() << endl;
     cout << "# times at same location = " << samePadCount << endl;
    return 0;
}
```

Two-dimensional walker

- One-d walker Current() returns an int as position
- Two-d walker Current() returns a Point as position
  - Both int and Point can be compared using ==
  - Both int and Point can be printed using <<

- Same program works for two-d walker, even though underneath the implementation is very different
  - Since the interfaces are the same/similar, client programs are easier to write once, use many times
  - Client code still needs to #include a different header and must link in a different (two-d) walker implementation

What's the Point?

- The two-dimensional walker uses `#include "point.h"`
  - This provides access to class Point declaration/interface
  - The class Point is actually defined using `struct Point`
  - In C++, a struct is a class in which everything is public by default
    - In a class, everything is private by default
    - A struct is really a hold-over from C, used in C++ for *plain old data*
  - Some programmers/designers don't like to use structs in C++, but use classes only
- We'll use struct when data is public, when the state is really more important than the behavior
  - Guideline, data is private accept in a struct, other options?

point.h

```
struct Point
{
  Point();
  Point(double px, double py);

  string tostring()                       const;
  double distanceFrom(const Point& p) const;
  double x;
  double y;
};
```

- **Two constructors, data is public, how is the (0,0) defined?**
  - **How is distance from (3,5) to (11,20) calculated?**
  - **How is a Point p printed?**

Other details from `point.h`

- Points can be compared with each other using ==, <, >=, etc.
- Point p can be printed using `cout << p << endl;`
  - Later we'll learn how to *overload* operators like this
  - For now we'll be clients, using Points like ints, BigInts, etc.

- The `struct Point` has constructors and other behavior
  - `distanceFrom` and `tostring` constitute the behavior
  - Some programmers think structs shouldn't have any functions, holdover from C rather than C++
- What is implemention of `Point::distanceFrom` like?

Other uses of structs

- In a program using free (non-class) functions, lots of data is often passed from one function to another
  - In class-based programs data is often, though not always, part of a class and a class object is passed

- Using structs to collect related data makes programs easier to read, modify, and maintain
  - Suppose you want to find mean, mode, and median of the lengths of words in a file, two alternatives:

```
void doFileStats(const string& filename,
                 double & mean, int & mode, int & median);

void doFileStats(const string& filename, FileData& data);
```

More struct conventions

- It's almost always worth including a constructor in a `struct`

```
struct FileData
{
    FileData()
    {
       myMean = 0.0;
       myMode = 0;
       myMedian = 0;
    }
    double myMean;
    int    myMode;
    int    myMedian;
};
```

- What other data might be included in `FileData`, what about other constructors?

Class (and struct) conventions

- For debugging and printing it's useful for classes to implement a function tostring(), that "stringizes" an object
  - Also useful in overloading `operator <<` for an object

```
Point p;
string s = p.tostring();
cout << s << " " << p << endl;
```

- When initializing data in a constructor, it's better to use an initializer list than to set values in the constructor body
  - Sometimes initializer lists are required (see next example), so using them at all times leads to more uniform coding that works in more situations

Initializer lists are sometimes required

- Consider a class that has a private `Dice` data member

```
class Game
{
  public:
    Game();
    // more functions
  private:
    Dice myDie;
    // more data
};
```

- The instance variable `myDie` must be given a # sides, this cannot be given in the .h file/declaration, must be provided in the .cpp file/class implementation
  - ➤ It's an error if an initializer list isn't use

Initializer lists

- Here are two versions of an initializer list for `Game::Game()`

```
Game::Game()
  : myDie(6)
{ }

// if there's more data, use initializer list
Game::Game()
  : myDie(6),
    myName("roulette")
{ }
```

- There can be code in constructor body to do more, e.g., read from a file
  - Sometimes it's useful to call private, helper functions

Mary Shaw

- **Software engineering and software architecture**
  - **Tools for constructing large software systems**
  - **Development is a small piece of total cost, maintenance is larger, depends on well-designed and developed techniques**
- **Interested in computer science, programming, curricula, and canoeing**

Three phases of creating a program

- **The preprocessor is a program that processes a file, processing all #include directives (and other preprocessor commands)**
  - **Takes a file, and creates a *translation unit***
  - **Replaces #include "foo.h" with contents of file foo.h, and does this recursively, for all #includes that foo includes and so on**
  - **Produces input to the next phase of program creation**

- **The compiler has a translation unit as input and produces compiled object code as output**
  - **The object code is platform/architecture specific, the source code is (in theory at least) the same on all platforms**
  - **Some compilers require special treatment, not up to standard C++**

From compiling to linking

- **The compilation phase creates an object file, but libraries and other files still need to be linked to create an executable**
  - **Header files like "dice.h" provide only the interface, enough for the compiler to know that a function call has the right parameters and is used correctly**
  - **The implemention file, "dice.cpp", must be compiled and included in the final executable, or the program won't work (call a dice function, but no one is home?)**

- **Linking combines object files, some of which may be collected in a library of related files, to create an executable**
  - **Link the standard library (iostream, for example)**
  - **Link other libraries depending on program, graphics, tapestry, other application-specific libraries**

Issues in creating a program

- **Programming environments create optimized or debug code**
  - **Use debug version to facilitate development**
  - **If you need optimization, use it only after a program works**

- **Some errors are compilation errors, typically language syntax or failure to find a #include'd header file**
  - **The preprocessor looks in standard places for header files, sometimes this list needs to be changed**

- **Other errors are linker errors, libraries or object files that are needed aren't included**
  - **Change programming environment parameters to find the libraries**