

(5 - 1) Object-Oriented Programming (OOP) and C++

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Key Concepts

- Object-Oriented Design
- Object-Oriented Programming (OOP)
- Class and Objects
- Data Encapsulation
- Abstraction/Information Hiding
- C++ I/O
- References and Reference Parameters
- Unary Scope Resolution Operator
- Function Overloading



Object-Oriented Design (OOD)

- Model software in ways that are similar to how people view/describe real-world objects
- Descriptions and designs include properties or attributes of the real-world objects
- The Unified Modeling Language (UML) provides a specification for illustrating properties of objects along with interactions between them



Object-Oriented Programming (OOP) (I)

- Programming language model which institutes mechanisms to support implementing object driven software systems
 - C++, C#, Java
- Procedural programming, such as instituted by C, is action oriented
- In C, the unit of programming is a function
- In C++ the unit is a `class`



Object-Oriented Programming (OOP) (II)

- We'll explore OOP with classes, encapsulation, objects, operator overloading, inheritance, and polymorphism
- We'll also explore generic programming with function templates and class templates



Classes and Objects

- What is a `class`?
 - A user defined type or data structure
 - Contains data members (attributes) and member functions (operations)
 - A blueprint for an object
- What is an object?
 - An instantiation of a class
 - The class is the type and the object is the variable with allocated memory for that type



Data Encapsulation (I)

- A way of organizing or wrapping of data/attributes and methods/operations into a structure (or capsule)
 - Demonstrated by objects
- Objects naturally impose encapsulation – attributes and operations are closely tied together
- How does making a function or class a `friend` of another class impact encapsulation?



Abstraction/Information Hiding (I)

- A design principle which states a design decision should be hidden from the rest of the system
- In other words, objects should communicate with each other through well-defined interfaces, but not know how other objects are implemented



Abstraction/Information Hiding (II)

- Prevents access to data aside from the methods specified by the object
- Guarantees integrity of data
- Access specifiers in C++ control the access to information
 - `public`, `protected`, **and** `private`



Programming in C++

- When programming in an object-oriented language, we'll be exposed to encapsulation, abstraction, and information hiding in action
- We need to start thinking in an object-oriented way so that we can leverage the software design benefits of objects and the richness of C++!
- Always remember, objects contain data and associated operations!



Basics of C++ and I/O (I)

- In C++, just like in C, every program begins execution with function `main ()`
- To perform input and output (I/O) we need to include the C++ Standard Library `<iostream>`
 - Essentially replaces `<stdio.h>`, but with even more richness and convenience



Basics of C++ and I/O (II)

- In tandem with including `<iostream>`, we'll need to use the following:
 - A standard output stream object (`std::cout`) and stream insertion operator (`<<`) to display information on the screen
 - Replaces the need for `printf ()`
 - A standard input stream object (`std::cin`) and the stream extraction operator (`>>`) to read data from the keyboard
 - Replaces the need for `scanf ()`



Basics of C++ and I/O Example

```
#include <iostream>
using std::cin; // replaces need for std:: in front of cin
using std::cout; // replaces need for std:: in front of cout
using std::endl; // replaces need for std:: in front of endl
int main (void)
{
    int n1 = 0;
    cout << "Enter a number: ";
    cin >> n1; // Notice no address of (&) required!

    int n2 = 0, sum = 0; // Can declare variables right
                        // before their use in C++!
    cout << "Enter a second number: ";
    cin >> n2;
    sum = n1 + n2;
    cout << "The sum is: " << sum << endl; // endl outputs a
                                           // newline, then flushes buffer

    return 0;
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```



References and Reference Parameters (I)

- There are two ways to pass arguments to functions in C++
 - Pass-by-value (PBV) – a copy of the contents/value of each argument is made and passed (on the function call stack) to the called function
 - One disadvantage of pass-by-value is copying the contents of a large data item or object introduces longer execution times and memory space
 - In general, should only be used with simple types
 - Passing-by-pointer falls under this category
 - Pass-by-reference (PBR) – NO copy of the contents/value of each argument is made
 - The called function can access the caller's data directly, and modify the data



References and Reference Parameters (II)

- Thoughts: we don't use pass-by-reference strictly so that we can modify the data in an object directly, in many cases we use it so that the overhead of copying data is circumvented
- We use the ampersand (&) to represent pass-by-reference
 - i.e. `void cube (int &n);` // this is a prototype
 - Don't confuse with the address of (&) operator!
Context determines which one's in play!
- Check out:
<http://www.cplusplus.com/articles/z6vU7k9E/>



References and Reference Parameters (III)

- We can return a reference to a variable as well – however we have to be very careful!
 - i.e. **int &** someFunction (int &n);
- If we return a reference to an automatic local variable, the variable becomes “undefined” when the function exits; unless the variable is declared as “static” (keyword)
 - References to undefined variables are called *dangling* references
 - Note: dangling references and dangling pointers are NOT the same!



References and Reference Parameters Example

```
...
void cubeByRef (int &n);
void cubeByPtr (int *pN);
int main (void)
{
    int n = 5;
    cubeByRef (n); // Don't need &, the formal parameter list indicates PBR
    cubeByPtr (&n); // Need address of (&) operator to satisfy pointer; applying PBV
    ...
}
void cubeByRef (int &n)
{
    n = n * n * n; // We have direct access to n, don't need to dereference;
                  // changes are retained
}
void cubeByPtr (int *pN)
{
    *pN = (*pN) * (*pN) * (*pN); // Need to dereference to indirectly change value
}
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```



Unary Scope Resolution Operator

- It's possible to declare local and global variables of the same name
 - Unary Scope Resolution Operator (::) allows a global variable to be accessed without confusing it with a local variable

...

```
int num = 42; // global variable
int main (void)
{
    double num = 100.25; // local variable
    cout << num << endl; // displays 100.25
    cout << ::num << endl; // displays 42
}
```



Function Overloading (I)

- The ability to define multiple functions with the same name
 - Requires that each function has different types of parameters and/or different number of parameters and/or different order of parameters
 - i.e. `int cube (int n);`
`double cube (double n);`
- The C++ compiler selects the appropriate function based on the *number*, *types*, and *order* of arguments in the function *call*



Function Overloading (II)

- We use function overloading to increase readability and understandability
 - Of course, we only want to overload functions that perform similar tasks



C++ Standard Template Library (STL) Class Vector

- STL class `vector` represents a more robust array with many more capabilities
- May operate with different types of data because they're templated!

– i.e. `vector<int> v1(10);` // declares a 10 element
// vector of integers

`vector<double> v2(5);` // declares a 5 element vector
// of doubles



Closing Thoughts

- OOP and C++ opens us up to an entirely different world!
- We need to start thinking more in terms of data and “capsules” instead of just actions and logic
- Learning C++ is a challenge, but provides features that will increase levels of production!



References

- P.J. Deitel & H.M. Deitel, *C++: How to Program* (9th ed.), Prentice Hall, 2014.



Collaborators

- Jack Hagemeister

