Fast Introduction to Object Oriented Programming and C++

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Note: a compilation of slides from Jacques de Wet, Ohio State University, Chad Willwerth, and Daniel Aliaga.
Outline

- Programming and C++
- C vs. C++
- Input/Output Library
- Object Classes
- Function and Operator Overloading
- Inheritance and Virtual Functions
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Object Oriented Programming (OOP)

- OOP models communication between objects
  - just as people send messages to one another, objects communicate via messages.
- OOP encapsulates data (attributes) and functions (behavior) into objects.
  - Objects have information hiding.
Object Oriented Programming (OOP) cont.

- Objects are *user-defined types* called *classes*.
- A *class* definition is an extension of a C struct.

- The variables are typically *private* or *protected* and the functions are typically *public*.
- *Structs* and *classes* are the *same in C++ (both* can have member functions or “methods”), but *struct* members are *public by default* and class members are *private by default*. 
C++

- Development of C in early ’70s
- Early ’80s, new language by Bjarne Stroustrup ➔ “C with Classes”
- October 1985 - first commercial release
- November 1997 – ANSI Standard for C++
- C++ is the most popular language now
  - Portability, flexibility, code reuse and quality
C++

Is C++ the best language? (Better than C?)

- Offers some nice features
- Choice of language though is a result of the particular problem and the environment
  - Nevertheless, bad programming results a bad program regardless of the chosen language
- Not only a new language, but a new way of thinking
- Additional support for programming, software engineering, and large projects
C++

Claimed advantages over C

1. Faster development time (code reuse)
2. Creating/using new data types is easier
3. Memory management easier \(\Rightarrow\) less leaks
4. Stricter syntax & type checking \(\Rightarrow\) less bugs
5. Data hiding easier to implement
6. Object-oriented (OO) concepts in C++ allows direct coding from an OO Analysis and Design document
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C versus C++

Differences:
- C++ is a superset of C
- Namespaces
- Variable declaration
- NULL-pointers vs. 0-pointers
- Stricter type checking
C versus C++

Differences:

- **Bool data type:** value of ‘true’ or ‘false’
- **Const vs. non-const**
  - e.g., `int i = (int)12.45;`
  - e.g., `const char *name = “Daniel”;`
  - e.g., `const char *p = name;`
C versus C++

Differences:

- ‘void’ parameter list
  - void function() and void function(void)
- Using C functions in a C++ application
  - extern “C”
- Function overloading is possible in C++
  - Same name, different parameter list
C versus C++

Differences:
- Default function arguments
- typedef – still allowed but not necessary
- Functions as part of a structure
- Function return values
  - In C, default is int
  - In C++ you have to specify the value, otherwise the compiler will give a warning.
C versus C++

// This is a comment that covers
// more than one line. It
// requires double slashes on
// each line.
C versus C++

inline float equation ( float x )
    { return x*x-5x+3; }

    // This solves problems that arise with

#define equation(x) (x*x)-5x+3
C versus C++

Differences:

- “new” instead of “malloc()”
- “delete instead of “free()”

  Example: “int *values = new values[10];”
  Example: “delete [] values;”
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- **Input/Output Library**
- Object Classes
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Input/Output Library in C++

- It is perfectly valid to use the same I/O statements in C++ as in C -- The very same `printf`, `scanf`, and other `stdio.h` functions that have been used until now.

- However, C++ provides an alternative with the new stream input/output features. The header file is named `iostream` and the stream I/O capabilities are accessible when you use the pre-processor declaration:

  ```cpp
  #include <iostream> // No “.h” on std headers
  using namespace std; // To avoid things like
                         // std::cout and std::cin
  ```
Input/Output Library in C++

Several new I/O objects available when you include the iostream header file. Two important ones are:

- `cin` // Used for keyboard input (std::cin)
- `cout` // Used for screen output (std::cout)

Both `cin` and `cout` can be combined with other member functions for a wide variety of special I/O capabilities in program applications.
Since `cin` and `cout` are C++ objects, they are somewhat "intelligent":

- They do not require the usual format strings and conversion specifications.
- They do automatically know what data types are involved.
- They do not need the address operator, `&`.
- They do require the use of the stream extraction (`>>`) and insertion (`<<`) operators.

The next slide shows an example of the use of `cin` and `cout`.
Example using cin and cout

#include <iostream>
using namespace std; // replace every cin and cout
// with std::cin and std::cout
// without this line

int main ( )
{
    int a, b; float k; char name[30];
    cout << "Enter your name\n" ;
    cin >> name ;
    cout << "Enter two integers and a float\n" ;
    cin >> a >> b >> k ;
    cout << "Thank you, " << name << ", you entered\n" ;
    cout << a << ", " << b << ", and " << k << \\
};
Enter your name
Rick
Enter two integers and a float
20  30  45.67
Thank you, Rick, you entered
20, 30, and 45.67
Input Stream Object Member Functions

\[
\text{cin.getline (array\_name, max\_size)};
\]

Example:
\[
\text{char name[40] ;}
\]
\[
\text{cin.getline (name, 40); // gets a string from keyboard and assigns to name}
\]
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- **Object Classes**
- Function and Operator Overloading
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Object Classes in C++

- Classes enable a C++ program to model objects that have:
  - attributes (represented by data members).
  - behaviors or operations (represented by member functions).

- Types containing data members and member function prototypes are normally defined in a C++ program by using the keyword class.
Object Classes in C++

- A class definition begins with the keyword `class`.
- The body of the class is contained within a set of braces, `{ } ;` (notice the semi-colon).
- Within the body, the keywords `private:` and `public:` specify the access level of the members of the class. Classes default to `private`.
- Usually, the data members of a class are declared in the `private:` section of the class and the member functions are in `public:` section.
- Private members of the class are normally not accessible outside the class, i.e., the information is hidden from "clients" outside the class.
Object Classes in C++

- A member function prototype which has the very same name as the name of the class may be specified and is called the constructor function.

- The definition of each member function is "tied" back to the class by using the binary scope resolution operator (::).

- The operators used to access class members are identical to the operators used to access structure members, e.g., the dot operator (.).
```cpp
#include <iostream>
#include <cstring> // This is the same as string.h in C
using namespace std;

class Numbers // Class definition
{
    public: // Can be accessed by a "client".
        Numbers ( ) ; // Class "constructor"
        void display ( ) ;
        void update ( ) ;
    private: // Cannot be accessed by "client"
        char name[30] ;
        int a ;
        float b ;
};
```
Classes Example (continued)

Numbers::Numbers ( ) // Constructor member function
{
    strcpy (name, "Unknown") ;
    a = 0;
    b = 0.0;
}

void Numbers::display ( ) // Member function
{
    cout << "\nThe name is " << name << "\n";
    cout << "The numbers are " << a << " and " << b
    << endl ;
}
Classes Example (continued)

```cpp
void Numbers::update () // Member function
{
    cout << "Enter name" << endl;
    cin.getline(name, 30);
    cout << "Enter a and b" << endl;
    cin >> a >> b;
}
```
int main ( )
{
    Numbers no1, no2;  // Create two objects of
    // the class "Numbers"

    no1.update ( ) ;  // Update the values of
    // the data members

    no1.display ( ) ;  // Display the current
    no2.display ( ) ;  // values of the objects
}

// Main program
Example Program Output

Enter name
   Rick Freuler
Enter a and b
   9876      5.4321
The name is Rick Freuler
The numbers are 9876 and 5.4321
The name is Unknown
The numbers are 0 and 0
#include <iostream>
#include <cstring>
using namespace std;

class Numbers // Class definition
{
    public:
        Numbers (char [ ] = "Unknown", int = 0, float = 0.0) ;
        void display ( ) ;
        void update ( ) ;
    private:
        char name[30];
        int a;
        float b;
} ;
More Detailed Classes Example (continued)

```cpp
Numbers::Numbers (char nm[], int j, float k)
{
    strcpy(name, nm);
    a = j;
    b = k;
}

void Numbers::update()
{
    cout << "Enter a and b" << endl;
    cin >> a >> b;
}
```
void Numbers::display( )
{
    cout << "\nThe name is " << name << "\n";
    cout << "The numbers are " << a << " and " << b
       << endl ;
}

int main ( )
{
    Numbers no1, no2 ("John Demel", 12345, 678.9);
    no1.display ( ) ;
    no2.display ( ) ;
}
More Detailed Example

Program Output

The name is Unknown
The numbers are 0 and 0

The name is John Demel
The numbers are 12345 and 678.9
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Function Overloading

- Same function name, different signatures
  - Does not include return type
    - Return type is not considered because it doesn’t have to be used

- Example:
  - `void Print( int n );`
  - `void Print( char c );`
  - `size_t Print( char* str );`
  - `void Print( float f, int precision );`
Name Decoration

- Compiler creates unique name for each function
  - Consists of function name, parameter number and types
  - Called *name decoration* or *name mangling*
  - Visible in “map file” created by linker
Overloading with Pointers

- Pointers to different types are distinct types
  - Works fine, e.g.:
    - void findData(char *s);
    - void findData(int *i);

- Array ↔ Pointer
  - Array notation and pointer notation is same function
    - int largest( int* values, int count );
    - int largest( int values[], int count );
Overloading with References

- Changing parameter to reference only changes *how* function is called
  - int func( int a );
  - int func( int& a );  // ambiguous function

- Non-const reference parameters may not call correct function
  - Function could change original value
  - Compiler will avoid it if possible
  - Solution: make reference parameters const
    - int func( const int a );  // make sense?
    - int func( const int &a); // make sense?
      - No?
      - Actually it does – for efficiency reasons: data not copied but referred too…
Overloading and Const

long larger( long a, long b );
long larger( const long a, const long b );

- What’s the difference?
  - Both are pass-by-value
  - Original value can’t be changed by either
  - No difference

- Const is only used for differences on pointers and references
  - Controls possible changes to data
Box box1(10, 15, 20);
Box box2(10, 15, 25);
if( box1 < box2 )
   // do something

Nothing more than a fancy syntax
  “syntactic sugar”
Why Overload Operators?

- Allows defining a function to be called when an pre-defined operator is found
  - Cannot create your own operators
  - Cannot overload all operators
- A great feature for making algorithms easier to read
  - But don’t go overboard
Operators to Overload

- All built-ins except:
  - Scope resolution ::
  - Conditional ?:
  - Member access .
  - Dereference to class member .*
  - Sizeof sizeof

- Can even overload:
  - new and delete
  - stream insertion/extraction
  - type conversion (explicit casts)
Introduction to Operator Overloading

class Box {
public:
    bool operator < (const Box& RHS) const;
    int volume( void ) const { return length * width * height; } 
... 
};

- Return type is obvious here
- LHS object is “this” object
- Parameter is RHS object
- Function doesn’t alter this object, so function is const
Implementing Overloaded Operator

```cpp
bool Box::operator < (const Box& RHS) const
{
    return volume() < RHS.volume();
}
```

- Note implied “this” pointer on first “volume()”
- Return statement calls 2 functions, compares values and returns results
- Usage: if( box1 < box2 ) …
  - Same as: if( box1.operator<(box2) )

Shortcuts for Relational Operators

Given equality (==) and less-than (<) operators, all other relational operators can be defined

- `!= ↔ !(a == b)`
- `> ↔ !(a < b) && !(a == b)`
- `<= ↔ (a < b) || (a == b)`
- etc.
Assignment Operator

- The 4\textsuperscript{th} (and last) function the compiler provides if you don’t
- Syntax: \textit{Type}\& operator = (const \textit{Type}\&);
- Returns reference for chaining
  - Returns itself (i.e. return *this;)
  - Const reference parameter avoids need for copy constructor
- Should check for assignment to self
  - Avoids problems with pointer members
  - if( this != &RHS ) …
Implementing an Assignment Operator

class Box {
public:
    Box& operator = (const Box& RHS) {
        if (this != &RHS) {
            length = RHS.length;
            width = RHS.width;
            height = RHS.height;
        }
        return *this;
    }
};
Optimizing Returns

- Creating a temporary object in return statement is excellent optimization
  - return Box( 10, 15, 20 );
- Not the same as creating a local temp variable and returning it
  - Causes constructor, copy to temp object, destructor calls
- Compiler knows there’s no need for a temp object created in a return statement
  - Creates it directly in caller’s lvalue location
Unusual Operators

- Index operator []
  - Returns a reference into some internal data
- new and delete
  - Allows custom memory management
  - An advanced topic for a later quarter
- Operator comma
  - Why bother?
- Operator ->
  - Defines “smart pointers” or *iterators*
  - Used frequently in C++ Standard Template Library (summer topic)
More Unusual Operators

- **Operator ( )**
  - Make your object look like a function call
  - Can be overloaded to have many signatures

- **Operator ->**
  - “pointer to member”
    - Essentially a pointer to a member function
  - Advanced topic
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Inheritance

- Allows extension of one “generic” data type with another more specific version
- The basis for polymorphism
- The heart of Object-Oriented Programming
- Uses the “Is-A” or “Is Kind Of” test
Inheritance Syntax

- **Syntax:**
  
  ```
  class Derived : public Base
  {
    ...
  };
  ```

- **Example:**
  
  ```
  class Carton : public Box
  {
    public:
    Carton( const std::string& c_strMaterial );
  private:
    const std::string m_strMaterial;
  };
  ```
Member Access Control with Inheritance

- **Review:**
  - public – Anyone outside the class has access
  - private – No one outside the class has access
  - protected – private to the outside world, but public to derived classes
Order of Construction

- Derived classes are extensions of base classes
  - Base classes must be created before they can be extended
- Base class constructor called by derived class before derived class constructor entered
Order of Destruction

- Derived classes are extensions of base classes
  - Derived classes must be destroyed before base class
- Destructors called from most derived to base
Calling Constructors Explicitly

- So far, base class default constructors called implicitly
- Sometimes you want to call a different base constructor
  - Sometimes base class default constructor doesn’t even exist
- Call in member initialization list
Copy Constructors Revisited

- Remember: default constructor called implicitly if nothing else specified
  - Causes base class not to get copied when derived class copy constructor invoked

- Derived class copy constructor must explicitly call base class copy constructor
Base Class Access Specifiers

- Controlled access to members based access specifiers inside base class so far
- Can override member access control for entire class by changing how base class is inherited
- Remember syntax: `class Derived : public Base { ... };`
- Changing “public” inheritance of base class alters definitions of internal access control
Public Base Class Inheritance

- When inheriting from base classes as “public” the normal definitions of access control pertain
- This is the most common

```cpp
class Derived : public Base {...};
```
Protected Base Class

Inheritance

- Inheriting base class as protected limits all public base class members to “protected” in derived class

```cpp
class Derived : protected Base {...};
```
Inheriting the base class as private makes the entire base class private in the derived class

class Derived : private Base {…};
Overloading Functions/Members in Inheritance Hierarchies

- What if you reuse a base class’s function or member variable name in a derived class?

- Basic scoping rules apply
  - Derived name is “more local”
  - Derived class version hides base class version
  - Use fully qualified name to access base class version
Object Slicing

class Carton : public Box {...};

■ A Carton “is a” Box

■ Legal to create a box object from a carton:
  Carton thin( “paper” );
  Box paper(thin);

■ Paper loses all Carton-related information
  □ Only retains data declared in Box
  □ Called object slicing

■ Can only move up a hierarchy tree
Overriding Inherited Behaviors

What if we want to change behavior in a derived class?

- e.g. Given a Shape object drawing a square is different than drawing a triangle
- Make an operation *polymorphic*
- Done with the *virtual* keyword
Virtual Functions

- Allows the selection of the correct function to be invoked at run-time
- Overload base class function in derived class
  - Same name, parameter list, const
  - Stopping here would only hide the function name, not override it
- Function declared as virtual in base class
  
  ```cpp
  virtual void Draw( void ) const;
  ```
  - Don’t have to mark as virtual in derived classes but recommended for clarity
- Derived class may or may not implement the function
  - Doesn’t matter—compiler selects most-derived implementation