Chapter 15 - C++ As A "Better C"

Outline

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15.1 Introduction

- First 14 Chapters
  - Procedural programming
  - Top-down program design with C

- Chapters 15 to 23
  - C++ portion of book
  - Object based programming (classes, objects, encapsulation)
  - Object oriented programming (inheritance, polymorphism)
  - Generic programming (class and function templates)

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15.2 C++

- C++
  - Improves on many of C's features
  - Has object-oriented capabilities
    - Increases software quality and reusability
  - Developed by Bjarne Stroustrup at Bell Labs
    - Called "C with classes"
    - C++ (increment operator) - enhanced version of C
  - Superset of C
    - Can use a C++ compiler to compile C programs
    - Gradually evolve the C programs to C++
- ANSI C++
  - Final version at http://www.ansi.org/
  - Free, older version at http://www.cygnus.com/misc/wp/

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15.3 A Simple Program: Adding Two Integers

- File extensions
  - C files: **`.c`**
  - C++ files: **`.cpp`** (which we use), **`.cxx`**, **`.C`** (uppercase)
- Differences
  - C++ allows you to "comment out" a line by preceding it with **`//`**
  - For example: **`// text to ignore`**
  - **`<iostream>`** - input/output stream header file
  - Return types - all functions must declare their return type
    - C does not require it, but C++ does
  - Variables in C++ can be declared almost anywhere
    - In C, required to declare variables in a block, before any executable statements

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15.3 A Simple Program: Adding Two Integers (II)

- Input/Output in C++
  - Performed with streams of characters
  - Streams sent to input/output objects
- Output
  - **`std::cout`** - standard output stream (connected to screen)
  - **`<<`** stream insertion operator ("put to")
  - **`std::cout << "hi";`**
    - Puts **`"hi"`** to **`std::cout`**, which prints it on the screen
- Input
  - **`std::cin`** - standard input object (connected to keyboard)
  - **`>>`** stream extraction operator ("get from")
  - **`std::cin >> myVariable;`**
    - Gets stream from keyboard and puts it into **`myVariable`**

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15.3 A Simple Program: Adding Two Integers (III)

- **`std::endl`**
  - "end line"
  - Stream manipulator - prints a newline and flushes output buffer
    - Some systems do not display output until "there is enough text to be worthwhile"
    - **`std::endl`** forces text to be displayed
- **`using`** statements
  - Allow us to remove the **`std::`** prefix
  - Discussed later
- Cascading
  - Can have multiple **<<** or **>>** operators in a single statement

```
std::cout << "Hello " << "there" << std::endl;
```

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15.4 C++ Standard Library

- C++ programs built from
  - Functions
  - Classes
    - Most programmers use library functions
- Two parts to learning C++
  - Learn the language itself
  - Learn the library functions
- Making your own functions
  - Advantage: you know exactly how they work
  - Disadvantage: time consuming, difficult to maintain efficiency and design well

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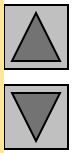
```
1  // Fig. 15.1: fig15_01.cpp
2  // Addition program
3  #include <iostream>
4
5  int main()
6  {
7     int integer1, integer2, sum;           // declaration
8
9     std::cout << "Enter first integer\n";  // prompt
10    std::cin >> integer1;                  // read an integer
11    std::cout << "Enter second integer\n"; // prompt
12    std::cin >> integer2;                  // read an integer
13    sum = integer1 + integer2;             // assignment of sum
14    std::cout << "Sum is " << sum << std::endl; // print sum
15
16    return 0;   // indicate that program ended successfully
17 }
```

```
Enter first integer
45
Enter second integer
72
Sum is 117
```



Outline

1. Load `<iostream>`

2. `main`

2.1 Initialize variables `integer1`, `integer2`, and `sum`

2.2 Print `"Enter first integer"`

2.2.1 Get input

2.3 Print `"Enter second integer"`

2.3.1 Get input

2.4 Add variables and put result into `sum`

2.5 Print `"Sum is"`

2.5.1 Output `sum`

2.6 exit (`return 0`)

Program Output

15.5 Header Files

- Header files
  - Each standard library has header files
    - Contain function prototypes, data type definitions, and constants
  - Files ending with **`.h`** are "old-style" headers
- User defined header files
  - Create your own header file
    - End it with **`.h`**
  - Use **`#include "myFile.h"`** in other files to load your header

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15.6 Inline Functions

- Function calls
  - Cause execution-time overhead
  - Qualifier **`inline`** before function return type "advises" a function to be inlined
    - Puts copy of function's code in place of function call
  - Speeds up performance but increases file size
  - Compiler can ignore the **`inline`** qualifier
    - Ignores all but the smallest functions

```
inline double cube( const double s )
   { return s * s * s; }
```

- Using statements
  - By writing **`using std::cout;`** we can write **`cout`** instead of **`std::cout`** in the program
  - Same applies for **`std::cin`** and **`std::endl`**

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15.6 Inline Functions (II)

- **`bool`**
  - Boolean - new data type, can either be **`true`** or **`false`**

C++ Keywords				
Keywords common to the C and C++ programming languages				
`auto`	`break`	`case`	`char`	`const`
`continue`	`default`	`do`	`double`	`else`
`enum`	`extern`	`float`	`for`	`goto`
`if`	`int`	`long`	`register`	`return`
`short`	`signed`	`sizeof`	`static`	`struct`
`switch`	`typedef`	`union`	`unsigned`	`void`
`volatile`	`while`			
C++ only keywords				
`asm`	`bool`	`catch`	`class`	`const_cast`
`delete`	`dynamic_cast`	`explicit`	`false`	`friend`
`inline`	`mutable`	`namespace`	`new`	`operator`
`private`	`protected`	`public`	`reinterpret_cast`	
`static_cast`	`template`	`this`	`throw`	`true`
`try`	`typeid`	`typename`	`using`	`virtual`
`wchar_t`				

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15.7 References and Reference Parameters

- Call by value
  - Copy of data passed to function
  - Changes to copy do not change original
- Call by reference
  - Function can directly access data
  - Changes affect original
- Reference parameter alias for argument
  - Use **&**

```
void change(int &variable)
  {
        variable += 3;
  }
```

    - Adds 3 to the original variable input
  - **int y = &x**
    - Changing **y** changes **x** as well

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15.7 References and Reference Parameters (II)

- Dangling references
  - Make sure to assign references to variables
  - If a function returns a reference to a variable, make sure the variable is **`static`**
    - Otherwise, it is automatic and destroyed after function ends
- Multiple references
  - Like pointers, each reference needs an **`&`**

```
int &a, &b, &c;
```

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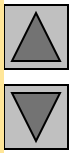
```
1  // Fig. 15.5: fig15_05.cpp
2  // Comparing call-by-value and call-by-reference
3  // with references.
4  #include <iostream>
5
6  using std::cout;
7  using std::endl;
8
9  int squareByValue( int );
10 void squareByReference( int & );
11
12 int main()
13 {
14    int x = 2, z = 4;
15
16    cout << "x = " << x << " before squareByValue\n"
17         << "Value returned by squareByValue: "
18         << squareByValue( x ) << endl
19         << "x = " << x << " after squareByValue\n" << endl;
20
21    cout << "z = " << z << " before squareByReference" << endl;
22    squareByReference( z );
23    cout << "z = " << z << " after squareByReference" << endl;
24
25    return 0;
26 }
27
28 int squareByValue( int a )
29 {
30    return a *= a;   // caller's argument not modified
31 }
```



Outline

1. Function prototypes

1.1 Initialize variables

2. Print `x`

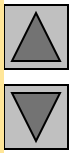
2.1 Call function and print `x`

2.2 Print `z`

2.3 Call function and print `z`

3. Function Definition

```
32
33 void squareByReference( int &cRef )
34 {
35    cRef *= cRef;     // caller's argument modified
36 }
```



Outline

3.1 Function Definition

Program Output

```
x = 2 before squareByValue
Value returned by squareByValue: 4
x = 2 after squareByValue

z = 4 before squareByReference
z = 16 after squareByReference
```

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15.8 Default Arguments and Empty Parameter Lists

- If function parameter omitted, gets default value
  - Can be constants, global variables, or function calls
  - If not enough parameters specified, rightmost go to their defaults

- Set defaults in function prototype

```
int myFunction( int x = 1, int y = 2, int z = 3 );
```

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15.8 Default Arguments and Empty Parameter Lists (II)

- Empty parameter lists
  - In C, empty parameter list means function takes any argument
    - In C++ it means function takes no arguments
  - To declare that a function takes no parameters:
    - Write **`void`** or nothing in parentheses
    - Prototypes:

```
void print1( void );
void print2();
```

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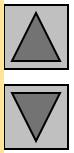
```
1  // Fig. 15.8: fig15_08.cpp
2  // Using default arguments
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7
8  int boxVolume( int length = 1, int width = 1, int height = 1 );
9
10 int main()
11 {
12    cout << "The default box volume is: " << boxVolume()
13         << "\n\nThe volume of a box with length 10,\n"
14         << "width 1 and height 1 is: " << boxVolume( 10 )
15         << "\n\nThe volume of a box with length 10,\n"
16         << "width 5 and height 1 is: " << boxVolume( 10, 5 )
17         << "\n\nThe volume of a box with length 10,\n"
18         << "width 5 and height 2 is: " << boxVolume( 10, 5, 2 )
19         << endl;
20
21    return 0;
22 }
23
24 // Calculate the volume of a box
25 int boxVolume( int length, int width, int height )
26 {
27    return length * width * height;
28 }
```



Outline

1. Function prototype (notice defaults)

2. `main`

2.1 Function calls (use default arguments)

3. Function definition

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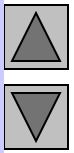

Outline

Program Output

```
The default box volume is: 1

The volume of a box with length 10,
width 1 and height 1 is: 10

The volume of a box with length 10,
width 5 and height 1 is: 50

The volume of a box with length 10,
width 5 and height 2 is: 100
```

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15.9 Unary Scope Resolution Operator

- Unary scope resolution operator (`::`)
  - Access global variables if a local variable has same name
  - Instead of **`variable`** use **`::variable`**
- **`static_cast<newType> (variable)`**
  - Creates a copy of **`variable`** of type **`newType`**
  - Convert **`int`**s to **`float`**s, etc.
- Stream manipulators
  - Can change how output is formatted
  - **`setprecision`** - set precision for **`float`**s (default 6 digits)
  - **`setiosflags`** - formats output
  - **`setwidth`** - set field width
  - Discussed in depth in Chapter 21

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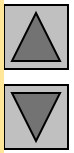
```
1  // Fig. 15.9: fig15_09.cpp
2  // Using the unary scope resolution operator
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7  using std::ios;
8
9  #include <iomanip>
10
11 using std::setprecision;
12 using std::setiosflags;
13 using std::setw;
14
15 const double PI = 3.14159265358979;
16
17 int main()
18 {
19    const float PI = static_cast< float >( ::PI );
20
21    cout << setprecision( 20 )
22         << "  Local float value of PI = " << PI
23         << "\nGlobal double value of PI = " << ::PI << endl;
24
25    cout << setw( 28 ) << "Local float value of PI = "
26         << setiosflags( ios::fixed | ios::showpoint )
27         << setprecision( 10 ) << PI << endl;
28    return 0;
29 }
```



Outline

1. Initialize global `const PI`

1.1 cast `global PI` to a local `float`

2. Print local and `global` values of `PI`

2.1 Vary precision and print local `PI`

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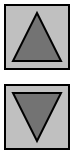
```
  Local float value of PI = 3.141592741012573242
Global double value of PI = 3.141592653589790007
  Local float value of PI = 3.1415927410
```



Outline

Program Output

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15.10 Function Overloading

- Function overloading:
  - Functions with same name and different parameters
  - Overloaded functions should perform similar tasks
    - Function to square **int**s and function to square **float**s

```
int square( int x) {return x * x;}
float square(float x) { return x * x; }
```

  - Program chooses function by signature
    - Signature determined by function name and parameter types
    - Type safe linkage - ensures proper overloaded function called

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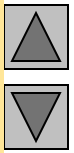

Outline

1. Define overloaded function

2. Function calls

```
1  // Fig. 15.10: fig15_10.cpp
2  // Using overloaded functions
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7
8  int square( int x ) { return x * x; }
9
10 double square( double y ) { return y * y; }
11
12 int main()
13 {
14    cout << "The square of integer 7 is " << square( 7 )
15         << "\nThe square of double 7.5 is " << square( 7.5 )
16         << endl;
17
18    return 0;
19 }
```

Program Output

```
The square of integer 7 is 49
The square of double 7.5 is 56.25
```

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15.11 Function Templates

- Function templates
  - Compact way to make overloaded functions
  - Keyword **`template`**
  - Keyword **`class`** or **`typename`** before every formal type parameter (built in or user defined)

```
template < class T >  // or template< typename T >
T square( T value1)
{
   return value1 * value1;
}
```

  - **`T`** replaced by type parameter in function call

```
int x;
int y = square(x);
```

    - If **`int`** parameter, all **`T`**'s become **`int`**s
    - Can use **`float`**, **`double`**, **`long`**...

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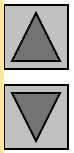
```
1  // Fig. 15.11: fig15_11.cpp
2  // Using a function template
3  #include <iostream>
4
5  using std::cout;
6  using std::cin;
7  using std::endl;
8
9  template < class T >
10 T maximum( T value1, T value2, T value3 )
11 {
12    T max = value1;
13
14    if ( value2 > max )
15       max = value2;
16
17    if ( value3 > max )
18       max = value3;
19
20    return max;
21 }
22
23 int main()
24 {
25    int int1, int2, int3;
26
27    cout << "Input three integer values: ";
28    cin >> int1 >> int2 >> int3;
29    cout << "The maximum integer value is: "
30         << maximum( int1, int2, int3 );          // int version
```



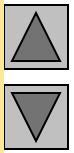
Outline

1. Define function template

2. `main`

2.1 Call `int` version of `maximum`

```
31
32    double double1, double2, double3;
33
34    cout << "\nInput three double values: ";
35    cin >> double1 >> double2 >> double3;
36    cout << "The maximum double value is: "
37         << maximum( double1, double2, double3 ); // double version
38
39    char char1, char2, char3;
40
41    cout << "\nInput three characters: ";
42    cin >> char1 >> char2 >> char3;
43    cout << "The maximum character value is: "
44         << maximum( char1, char2, char3 )        // char version
45         << endl;
46
47    return 0;
48 }
```



Outline

2.2 Call `double` version of `maximum`

2.3 Call `char` version of `maximum`

Program Output

```
Input three integer values: 1 2 3
The maximum integer value is: 3
Input three double values: 3.3 2.2 1.1
The maximum double value is: 3.3
Input three characters: A C B
The maximum character value is: C
```

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