IS 0020
Program Design and Software Tools

Introduction to C++ Programming

Lecture 1
May 10, 2004

Course Information

- Lecture:
  - James B D Joshi
  - Mondays: 6:00-8.50 PM
    - One (two) 15 (10) minutes break(s)
  - Office Hours: Wed 3:00-5:00PM/Appointment
  - TA: Ming Mao
- Pre-requisite
  - IS 0015 Data Structures and Programming Techniques
- Textbook
  - ***C++ How to Program***- Fourth Edition, by H. M. Deitel, P. J. Deitel, Prentice Hall, New Jersey, 2003, ISBN: 0-13-038474.

Course Information

- Course Description
  - An introduction to the development of programs using C++.
  - Emphasis is given to the development of program modules that can function independently.
    - Object-oriented design
  - The theory of data structures and programming language design is continued.

Grading

- Quiz 10% (in the beginning of the class; on previous lecture)
- Homework/Programming Assignments 50% (typically every week)
- Midterm 20%
- Comprehensive Final 20%

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Course Policy

- Your work MUST be your own
  - Zero tolerance for cheating
  - Discussing problems is encouraged, but each must present his own answers
  - You get an F for the course if you cheat in anything however small – NO DISCUSSION
- Homework
  - There will be penalty for late assignments (15% each day)
  - Ensure clarity in your answers – no credit will be given for vague answers
  - Homework is primarily the GSA's responsibility
- Check webpage for everything!
  - You are responsible for checking the webpage for updates

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Computer Languages

- Machine language
  - Generally consist of strings of numbers - Ultimately 0s and 1s - Machine-dependent
  - Example: **+1300042774**
    +1400593419
- Assembly language
  - English-like abbreviations for elementary operations
  - Incomprehensible to computers - Convert to machine language
  - Example:

```
LOAD   BASEPAY
ADD    OVERPAY
STORE  GROSSPAY
```

- High-level languages
  - Similar to everyday English, use common mathematical notations
  - Compiler/Interpreter
  - Example:

```
grossPay = basePay + overTimePay
```


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History of C and C++

- History of C
  - Evolved from two other programming languages
    - BCPL and B: "Typeless" languages
  - Dennis Ritchie (Bell Lab): Added typing, other features
  - 1989: ANSI standard/ ANSI/ISO 9899: 1990
- History of C++
  - Early 1980s: Bjarne Stroustrup (Bell Lab)
  - Provides capabilities for object-oriented programming
    - Objects: reusable software components
    - Object-oriented programs
- Building block approach" to creating programs
  - C++ programs are built from pieces called classes and functions
  - C++ standard library: Rich collections of existing classes and functions

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Structured/OO Programming

- Structured programming (1960s)
  - Disciplined approach to writing programs
  - Clear, easy to test and debug, and easy to modify
  - E.g.Pascal:1971: Niklaus Wirth
- OOP
  - "Software reuse"
  - "Modularity"
  - "Extensible"
  - More understandable, better organized and easier to maintain than procedural programming

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Basics of a Typical C++ Environment

- C++ systems
  - Program-development environment
  - Language
  - C++ Standard Library
- C++ program names extensions
  - .cpp
  - .cxx
  - .cc
  - .C

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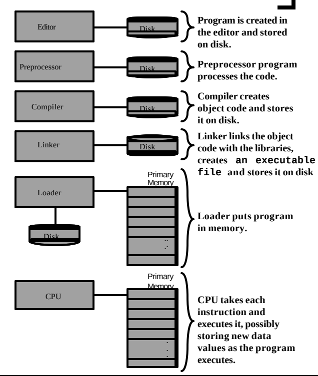
Basics of a Typical C++ Environment

Phases of C++ Programs:

1. Edit
2. Preprocess
3. Compile
4. Link
5. Load
6. Execute



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Basics of a Typical C++ Environment

- Common Input/output functions
  - **`cin`**
    - Standard input stream
    - Normally keyboard
  - **`cout`**
    - Standard output stream
    - Normally computer screen
  - **`cerr`**
    - Standard error stream
    - Display error messages
- Comments: C's comment /* .. */ OR Begin with **`// or`**
- Preprocessor directives: Begin with **`#`**
  - Processed before compiling

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A Simple Program: Printing a Line of Text

- Standard output stream object
  - **`std::cout`**
  - "Connected" to screen
  - **`<<`**
    - Stream insertion operator
    - Value to right (right operand) inserted into output stream
- Namespace
  - **`std::`** specifies that entity belongs to "namespace" **`std`**
  - **`std::`** removed through use of **`using`** statements
- Escape characters: **`\`**
  - Indicates "special" character output

```
// Fig. 1.2: fig01_02.cpp
// A first program in C++.
#include <iostream>

// function main begins program execution
int main()
{
   std::cout << "Welcome to C++!\n";

   return 0;   // indicate that program ended successfully

} // end function main
```

```
Welcome to C++!
```

Outline

fig01_02.cpp
(1 of 1)

fig01_02.cpp
output (1 of 1)

A Simple Program: Printing a Line of Text

Escape Sequence	Description
`\n`	Newline. Position the screen cursor to the beginning of the next line.
`\t`	Horizontal tab. Move the screen cursor to the next tab stop.
`\r`	Carriage return. Position the screen cursor to the beginning of the current line; do not advance to the next line.
`\a`	Alert. Sound the system bell.
`\\`	Backslash. Used to print a backslash character.
`\"`	Double quote. Used to print a double quote character.

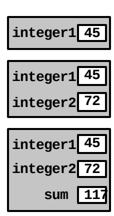
Memory Concepts

- Variable names
  - Correspond to actual locations in computer's memory
  - Every variable has name, type, size and value
  - When new value placed into variable, overwrites previous value

  - std::cin >> integer1;
  - Assume user entered 45

  - std::cin >> integer2;
  - Assume user entered 72

  - sum = integer1 + integer2;



Arithmetic

- Arithmetic calculations
  - `*` : Multiplication
  - `/` : Division
    - Integer division truncates remainder
      - `7 / 5` evaluates to 1
  - `%` : Modulus operator returns remainder
      - `7 % 5` evaluates to 2

Operator(s)	Operation(s)	Order of evaluation (precedence)
`()`	Parentheses	Evaluated first. If the parentheses are nested, the expression in the innermost pair is evaluated first. If there are several pairs of parentheses "on the same level" (i.e., not nested), they are evaluated left to right.
`*`, `/`, or `%`	Multiplication Division Modulus	Evaluated second. If there are several, they re evaluated left to right.
`+` or `-`	Addition Subtraction	Evaluated last. If there are several, they are evaluated left to right.

Decision Making: Equality and Relational Operators

- **`if`** structure
  - Make decision based on truth or falsity of condition
    - If condition met, body executed
    - Else, body not executed
- Equality and relational operators
  - Equality operators
    - Same level of precedence
  - Relational operators
    - Same level of precedence
  - Associate left to right

Decision Making: Equality and Relational Operators

Standard algebraic equality operator or relational operator	C++ equality or relational operator	Example of C++ condition	Meaning of C++ condition
Relational operators			
>	`>`	`x > y`	`x` is greater than `y`
<	`<`	`x < y`	`x` is less than `y`
≥	`>=`	`x >= y`	`x` is greater than or equal to `y`
≤	`<=`	`x <= y`	`x` is less than or equal to `y`
Equality operators			
=	`==`	`x == y`	`x` is equal to `y`
≠	`!=`	`x != y`	`x` is not equal to `y`

Algorithms /pseudocode

- Computing problems
  - Solved by executing a series of actions in a specific order
- Algorithm: a procedure determining
  - Actions to be executed
  - Order to be executed
  - Example: recipe
- Program control
  - Specifies the order in which statements are executed
- Pseudocode
  - Artificial, informal language used to develop algorithms
  - Similar to everyday English

Control Structures

- Sequential execution
  - Statements executed in order
- Transfer of control
  - Next statement executed *not* next one in sequence
  - Structured programming – "goto"-less programming
- 3 control structures to build any program
  - Sequence structure
    - Programs executed sequentially by default
  - Selection structures
    - **`if`**, **`if/else`**, **`switch`**
  - Repetition structures
    - **`while`**, **`do/while`**, **`for`**

Keywords

- C++ keywords
  - Cannot be used as identifiers or variable names

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`				

Control Structures

- Flowchart
  - Graphical representation of an algorithm
  - Special-purpose symbols connected by arrows (flowlines)
  - Rectangle symbol (action symbol)
    - Any type of action
  - Oval symbol
    - Beginning or end of a program, or a section of code (circles)

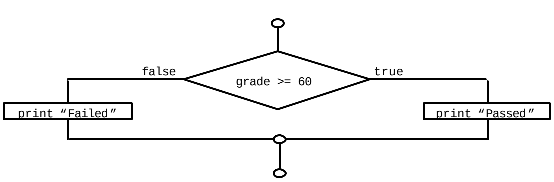
Exercise: Find greater of three numbers

`if/else` Selection Structure

- Ternary conditional operator (**`?:`**)
  - Three arguments (condition, value if **`true`**, value if **`false`**)
- Code could be written:

```
cout << ( grade >= 60 ? "Passed" : "Failed" );
```

Condition **Value if true** **Value if false**



while Repetition Structure

- Repetition structure
  - **Counter-controlled**
    - **While/do while** loop: repeated until condition becomes false
    - **For**: loop repeated until counter reaches certain value Flowchart representation?
  - **Sentinel value**
    - Indicates "end of data entry"
    - Sentinel chosen so it cannot be confused with regular input
- Example

```
int product = 2;
while ( product <= 1000 ) {
   product = 2 * product;
    cout << product;
}
```

Flowchart representation?
What is the output?

switch Multiple-Selection Structure

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- **switch**
  - Test variable for multiple values
  - Series of **case** labels and optional **default** case

```
switch ( variable ) {
     case value1:       // taken if variable == value1
             statements
             break;      // necessary to exit switch

     case value2:
     case value3:       // taken if variable == value2 or == value3
             statements
             break;

     default:           // taken if none matches
             statements
             break;
}
```


break and continue Statements

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- **break** statement
  - Immediate exit from **while**, **for**, **do/while**, **switch**
  - Program continues with first statement after structure
- Common uses
  - Escape early from a loop
  - Skip the remainder of **switch**

Logical Operators

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- Used as conditions in loops, **if** statements
- **&&** (logical **AND**)
  - **true** if both conditions are **true**

```
if ( gender == 1 && age >= 65 )
   ++seniorFemales;
```

- **||** (logical **OR**)
  - **true** if either of condition is **true**

```
if ( semesterAverage >= 90 || finalExam >= 90 )
   cout << "Student grade is A" << endl;
```


Logical Operators

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- **!** (logical **NOT**, logical negation)
  - Returns **true** when its condition is **false**, & vice versa

```
if ( !( grade == sentinelValue ) )
   cout << "The next grade is " << grade << endl;
```

Alternative:

```
if ( grade != sentinelValue )
   cout << "The next grade is " << grade << endl;
```

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Confusing Equality (==) and Assignment (=) Operators

- Common error
  - Does not typically cause syntax errors
- Aspects of problem
  - Expressions that have a value can be used for decision
    - Zero = false, nonzero = true
  - Assignment statements produce a value (the value to be assigned)

```
if == was replaced with =
   if ( payCode = 4 )
      cout << "You get a bonus!" << endl;
```

What happens?

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Confusing Equality (==) and Assignment (=) Operators

- *Lvalues*
  - Expressions that can appear on left side of equation
  - Can be changed
    `x = 4;`
- *Rvalues*
  - Only appear on right side of equation
  - Constants, such as numbers (i.e. cannot write **`4 = x;`**)
- *Lvalues* can be used as *rvalues*, but not vice versa

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Structured-Programming Summary

- Structured programming
  - Programs easier to understand, test, debug and modify
- Rules for structured programming
  - Only use single-entry/single-exit control structures
  - Rules
    1) Begin with the "simplest flowchart"
    2) Any rectangle (action) can be replaced by two rectangles (actions) in sequence
    3) Any rectangle (action) can be replaced by any control structure (sequence, if, if/else, switch, while, do/while or for)
    4) Rules 2 and 3 can be applied in any order and multiple times

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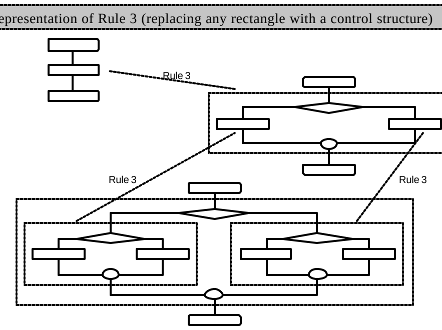
Structured-Programming Summary

Representation of Rule 3 (replacing any rectangle with a control structure)



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Program Components in C++

- Modules: *functions* and *classes*
- Programs use new and "prepackaged" modules
  - New: programmer-defined functions, classes
  - Prepackaged: from the standard library
- Functions invoked by function call
  - Function name and information (arguments) it needs
- Function definitions
  - Only written once
  - Hidden from other functions

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Functions

- Functions
  - Modularize a program
  - Software reusability
    - Call function multiple times
- Local variables
  - Known only in the function in which they are defined
  - All variables declared in function definitions are local variables
- Parameters
  - Local variables passed to function when called
  - Provide outside information

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Math Library Functions

- Perform common mathematical calculations
  - Include the header file **`<cmath>`**
- Functions called by writing
  - *functionName* (*argument*); or
  - *functionName* (*argument1*, *argument2*, …);
- Example
  `cout << sqrt( 900.0 );`
  - All functions in math library return a **`double`**
- Function arguments can be
  - Constants: **`sqrt( 4 );`**
  - Variables: **`sqrt( x );`**
  - Expressions:
    - **`sqrt( sqrt( x ) ) ;`**
    - **`sqrt( 3 - 6x );`**
- Other functions
  - **`ceil(x), floor(x), log10(x), etc.`**

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Function Definitions

- Function prototype
  - **`int square( int );`**
- Calling/invoking a function
  - **`square(x);`**
- Format for function definition

  return-value-type function-name **(** *parameter-list* **)**
  {
  declarations and statements
  }
- Prototype must match function definition
  - Function prototype
    ```
    double maximum( double, double, double );
    ```
  - Definition
    ```
    double maximum( double x, double y, double z )
    {
     …
    }
    ```

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Function Definitions

- Example function

```
int square( int y )
{
  return y * y;
}
```

- **`return`** keyword
  - Returns data, and control goes to function's caller
    - If no data to return, use **`return;`**
  - Function ends when reaches right brace
    - Control goes to caller
- Functions cannot be defined inside other functions

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Function Prototypes

- Function signature
  - Part of prototype with name and parameters
    - **`double maximum( double, double, double );`**

      Function signature
- Argument Coercion
  - Force arguments to be of proper type
    - Converting **`int`** (4) to **`double`** (4.0)

    `cout << sqrt(4)`
  - Conversion rules
    - Arguments usually converted automatically
    - Changing from **`double`** to **`int`** can truncate data
      - 3.4 to 3
  - Mixed type goes to highest type (promotion)

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Function Prototypes

Data types	
`long double`	
`double`	
`float`	
`unsigned long int`	(synonymous with `unsigned long`)
`long int`	(synonymous with `long`)
`unsigned int`	(synonymous with `unsigned`)
`int`	
`unsigned short int`	(synonymous with `unsigned short`)
`short int`	(synonymous with `short`)
`unsigned char`	
`char`	
`bool`	(`false` becomes 0, `true` becomes 1)

Fig. 3.5 Promotion hierarchy for built-in data types.

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Header Files

- Header files contain
  - Function prototypes
  - Definitions of data types and constants
- Header files ending with .h
  - Programmer-defined header files

    `#include "myheader.h"`
- Library header files

    `#include <cmath>`

Enumeration: enum

- Enumeration
  - Set of integers with identifiers

  enum *typeName* **{***constant1*, *constant2*…**};**
  - Constants start at 0 (default), incremented by 1
  - Constants need unique names
  - Cannot assign integer to enumeration variable
    - Must use a previously defined enumeration type
- Example

```
enum Status {CONTINUE, WON, LOST};
Status enumVar;
enumVar = WON; // cannot do enumVar = 1
```


Storage Classes

- Variables have attributes
  - Have seen name, type, size, value
  - Storage class
    - How long variable exists in memory
  - Scope
    - Where variable can be referenced in program
  - Linkage
    - For multiple-file program which files can use it

Storage Classes

- Automatic storage class
  - Variable created when program enters its block
  - Variable destroyed when program leaves block
  - Only local variables of functions can be automatic
    - Automatic by default
    - keyword **auto** explicitly declares automatic
  - **register** keyword
    - Hint to place variable in high-speed register
    - Good for often-used items (loop counters)
    - Often unnecessary, compiler optimizes
  - Specify either **register** or **auto**, not both
    - **register int counter = 1;**

Storage Classes

- Static storage class
  - Variables exist for entire program
    - For functions, name exists for entire program
  - May not be accessible, scope rules still apply
- **auto** and **register** keyword
  - local variables in function
  - **register** variables are kept in CPU registers
- **static** keyword
  - Local variables in function
  - Keeps value between function calls
  - Only known in own function
- **extern** keyword
  - Default for global variables/functions
    - Globals: defined outside of a function block
  - Known in any function that comes after it

Scope Rules

- Scope
  - Portion of program where identifier can be used
- File scope
  - Defined outside a function, known in all functions
  - Global variables, function definitions and prototypes
- Function scope
  - Can only be referenced inside defining function
  - Only labels, e.g., identifiers with a colon (`case:`)

Scope Rules

- Block scope
  - Begins at declaration, ends at right brace **}**
    - Can only be referenced in this range
  - Local variables, function parameters
  - Local **`static`** variables still have block scope
    - Storage class separate from scope
- Function-prototype scope
  - Parameter list of prototype
  - Names in prototype optional
    - Compiler ignores
  - In a single prototype, name can be used once

Outline

```
// Fig. 3.12: fig03_12.cpp
// A scoping example.
#include <iostream>

using std::cout;
using std::endl;

void useLocal( void );
void useStaticLocal( void )
void useGlobal( void );       // function prototype

int x = 1;      // global vari

int main()
{
   int x = 5;   // local variable to main

   cout << "local x in main's out

   { // start new scope

      int x = 7;

      cout << "local x in main's inner scope is " << x << endl;

   } // end new scope
```

Local/global? Scope?

Local/global? Scope?

Local/global? Scope?

fig03_12.cpp
(1 of 5)

Outline

```

   cout << "local x in main's outer scope is " << x << endl;

   useLocal();       // useLocal has local x
   useStaticLocal(); // useStaticLocal has static local x
   useGlobal();      // useGlobal uses global x
   useLocal();       // useLocal reinitializes its local x
   useStaticLocal(); // static local x retains its prior value
   useGlobal();      // global x also retains its value

   cout << "\nlocal x in main is " << x << endl;

   return 0;   // indicates successful termination

} // end main

```

fig03_12.cpp
(2 of 5)

```
// useLocal reinitializes local variable x during each call
void useLocal( void )
{
   int x = 25;  // initialized each time useLocal is called

   cout << endl << "local x is " << x
        << " on entering useLocal" << endl;
   ++x;
   cout << "local x is " << x
        << " on exiting useLocal" << endl;

} // end function useLocal

```

Local/global? Scope?

Outline

fig03_12.cpp
(3 of 5)


```
// useStaticLocal initializes static local variable x only the
// first time the function is called; value of x is saved
// between calls to this function
void useStaticLocal( void )
{
   // initialized only first time useStaticLocal is called
   static int x = 50;

   cout << endl << "local static x is " << x
        << " on entering useStaticLocal" << endl;
   ++x;
   cout << "local static x is " << x
        << " on exiting useStaticLocal" << endl;

} // end function useStaticLocal

```

Local/global? Scope?

Outline

fig03_12.cpp
(4 of 5)


```
// useGlobal modifies global variable x during each call
void useGlobal( void )
{
   cout << endl << "global x is " << x
        << " on entering useGlobal" << endl;
   x *= 10;
   cout << "global x is " << x
        << " on exiting useGlobal" << endl;

} // end function useGlobal
```

Local variable?
Global variable?

```
local x in main's outer scope is 5
local x in main's inner scope is 7
local x in main's outer scope is 5

local x is 25 on entering useLocal
local x is 26 on exiting useLocal

local static x is 50 on entering useStaticLocal
local static x is 51 on exiting useStaticLocal

global x is 1 on entering useGlobal
global x is 10 on exiting useGlobal
```

Outline

fig03_12.cpp
(5 of 5)

fig03_12.cpp
output (1 of 2)

Recursion

- Recursive functions
  - Functions that call themselves
  - Can only solve a base case
- If not base case
  - Break problem into smaller problem(s)
  - Launch new copy of function to work on the smaller problem (recursive call/recursive step)
    - Slowly converges towards base case
    - Function makes call to itself inside the return statement
  - Eventually base case gets solved
    - Answer works way back up, solves entire problem

Recursion

- Example: factorial

  *n! = n * (n – 1) * (n – 2) * … * 1*

  – Recursive relationship (n! = n * (n – 1)!)

  *5! = 5 * 4!*

  *4! = 4 * 3!…*

  – Base case (1! = 0! = 1)

Outline

fig03_14.cpp
(1 of 2)

```
// Fig. 3.14: fig03_14.cpp
// Recursive factorial function.
#include <iostream>

using std::cout;
using std::endl;

#include <iomanip>

using std::setw;

unsigned long factorial( unsigned long ); // function prototype

int main()
{
   // Loop 10 times. During each iteration, calculate
   // factorial( i ) and display result.
   for ( int i = 0; i <= 10; i++ )
      cout << setw( 2 ) << i << "! = "
           << factorial( i ) << endl;

   return 0;  // indicates successful termination

} // end main
```

Data type **`unsigned long`** can hold an integer from 0 to 4 billion.

Outline

fig03_14.cpp
(2 of 2)

fig03_14.cpp
output (1 of 1)

```
// recursive definition of function fac
unsigned long factorial( unsigned long
{
   // base case
   if ( number <= 1 )
      return 1;

   // recursive step
   else
      return number * factorial( number - 1 );

} // end function factorial
```

The base case occurs when we have **`0!`** or **`1!`**. All other cases must be split up (recursive step).

```
 0! = 1
 1! = 1
 2! = 2
 3! = 6
 4! = 24
 5! = 120
 6! = 720
 7! = 5040
 8! = 40320
 9! = 362880
10! = 3628800
```


Example Using Recursion: Fibonacci Series

- Fibonacci series: 0, 1, 1, 2, 3, 5, 8...
  – Each number sum of two previous ones
  – Example of a recursive formula:
    - *fib(n) = fib(n-1) + fib(n-2)*
- C++ code for Fibonacci function

```
long fibonacci( long n )
{
  if ( n == 0 || n == 1 )  // base case
     return n;
  else
   return fibonacci( n - 1 ) +
          fibonacci( n – 2 );
}
```

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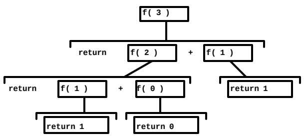
Example Using Recursion: Fibonacci Series



- Order of operations
  - `return fibonacci( n - 1 ) + fibonacci( n - 2 );`
- Recursive function calls
  - Each level of recursion doubles the number of function calls
    - 30th number = 2^30 ~ 4 billion function calls
  - Exponential complexity

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Recursion vs. Iteration

- Repetition
  - Iteration: explicit loop
  - Recursion: repeated function calls
- Termination
  - Iteration: loop condition fails
  - Recursion: base case recognized
- Both can have infinite loops
- Balance between performance (iteration) and good software engineering (recursion)

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Inline Functions

- Inline functions
  - Keyword **`inline`** before function
  - Asks the compiler to copy code into program instead of making function call
    - Reduce function-call overhead
    - Compiler can ignore **`inline`**
  - Good for small, often-used functions
- Example

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

  - **`const`** tells compiler that function does not modify **`s`**

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References and Reference Parameters

- Call by value
  - Copy of data passed to function
  - Changes to copy do not change original
  - Prevent unwanted side effects
- Call by reference
  - Function can directly access data
  - Changes affect original
- Reference parameter
  - Alias for argument in function call
    - Passes parameter by reference
  - Use **`&`** after data type in prototype
    - **`void myFunction( int &data )`**
    - Read "**`data`** is a reference to an **`int`**"
  - Function call format the same
    - However, original can now be changed

References and Reference Parameters

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- Pointers
  - Another way to pass-by-refernce
- References as aliases to other variables
  - Refer to same variable
  - Can be used within a function

```
int count = 1;     // declare integer variable count
int &cRef = count; // create cRef as an alias for count
++cRef; // increment count (using its alias)
```

- References must be initialized when declared
  - Otherwise, compiler error
  - Dangling reference
    - Reference to undefined variable

Default Arguments

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- Function call with omitted parameters
  - If not enough parameters, rightmost go to their defaults
  - Default values
    - Can be constants, global variables, or function calls
- Set defaults in function prototype

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

  - **`myFunction(3)`**
    - **`x = 3`**, **`y`** and **`z`** get defaults (rightmost)
  - **`myFunction(3, 5)`**
    - **`x = 3`**, **`y = 5`** and **`z`** gets default

Unitary Scope Resolution Operator

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- Unary scope resolution operator (**`::`**)
  - Access global variable if local variable has same name
  - Not needed if names are different
  - Use **`::variable`**
    - **`y = ::x + 3;`**
  - Good to avoid using same names for locals andglobals

Function Overloading

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- Function overloading
  - Functions with same name and different parameters
  - Should perform similar tasks
    - i.e., 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; }
```

- Overloaded functions distinguished by signature
  - Based on name and parameter types (order matters)
  - Name mangling
    - Encode function identifier with no. and types of parameters
  - Type-safe linkage
    - Ensures proper overloaded function called

Function Templates

- Compact way to make overloaded functions
  - Generate separate function for different data types
- Format
  - Begin with keyword **template**
  - Formal type parameters in brackets **<>**
    - Every type parameter preceded by **typename** or **class** (synonyms)
    - Placeholders for built-in types (i.e., **int**) or user-defined types
    - Specify arguments types, return types, declare variables
  - Function definition like normal, except formal types used

Function Templates

- Example

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

  - **T** is a formal type, used as parameter type
    - Above function returns variable of same type as parameter
  - In function call, T replaced by real type
    - If **int**, all **T**'s become **int**s

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



```
// Fig. 3.27: fig03_27.cpp
// Using a function template.
#include <iostream>

using std::cout;
using std::cin;
using std::endl;

// definition of function template maximum
template < class T >  // or template < typename T >
T maximum( T value1, T value2, T value3 )
{
   T max = value1;

   if ( value2 > max )
      max = value2;

   if ( value3 > max )
      max = value3;

   return max;

} // end function template maximum

```

Formal type parameter **T** placeholder for type of data to be tested by **maximum**

maximum expects all parameters to be of the same type.


```
int main()
{
   // demonstrate maximum with int values
   int int1, int2, int3;

   cout << "Input three integer values: ";
   cin >> int1 >> int2 >> int3;

   // invoke int version of maximum
   cout << "The maximum integer value is: "
        << maximum( int1, int2, int3 );

   // demonstrate maximum with double values
   double double1, double2, double3;

   cout << "\n\nInput three double values: ";
   cin >> double1 >> double2 >> double3;

   // invoke double version of maximum
   cout << "The maximum double value is: "
        << maximum( double1, double2, double3 );

```

maximum called with various data types.

Outline

```
   // demonstrate maximum with char values
   char char1, char2, char3;

   cout << "\n\nInput three characters: ";
   cin >> char1 >> char2 >> char3;

   // invoke char version of maximum
   cout << "The maximum character value is: "
        << maximum( char1, char2, char3 )
        << endl;

   return 0;  // indicates successful termination

} // end main
```

```
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
```

fig03_27.cpp
(3 of 3)

fig03_27.cpp
output (1 of 1)