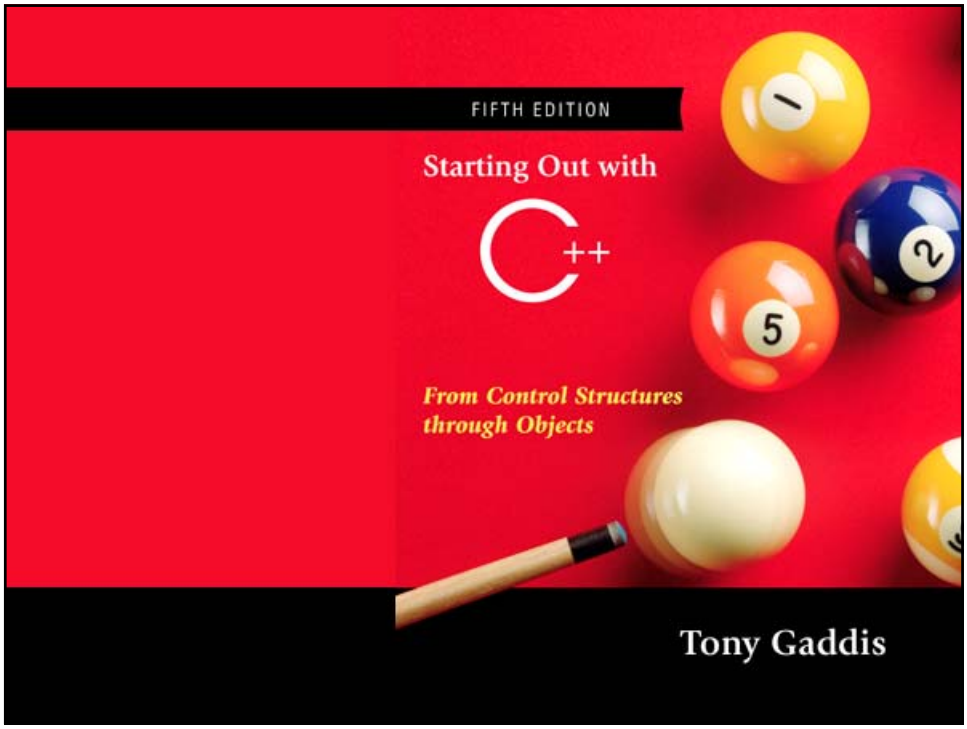
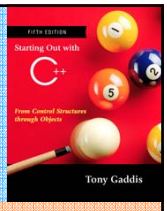


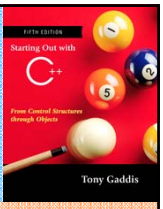
Chapter

1

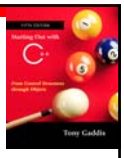
Introduction to Computers and Programming



PEARSON Addison Wesley



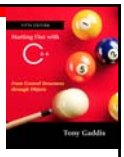
1.1 Why Program?



What is a Computer?

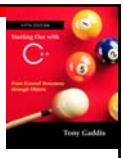
- A computer is a device that under the direction and control of a program performs four basic functions:
  - input
  - output
  - processing
  - storage.

What is Computer Science?



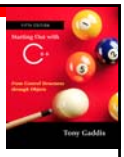
- Computer science is the study of algorithms, including
  - Their formal and mathematical properties
  - Their hardware realizations
  - Their linguistic realizations
  - Their applications

What is an Algorithm?



- An algorithm is a well-ordered collection of unambiguous and effectively computable operations that, when executed, produces a result and halts in a finite amount of time.

Why Program?

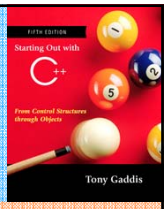


Computer – programmable machine designed to follow instructions

Program – instructions in computer memory to make it do something

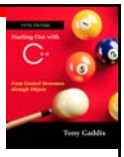
Programmer – person who writes instructions (programs) to make computer perform a task

SO, without programmers, no programs; without programs, a computer cannot do anything



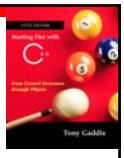
1.2 Computer Systems: Hardware and Software

Main Hardware Component Categories:



1. Central Processing Unit (CPU)
2. Main Memory
3. Secondary Memory / Storage
4. Input Devices
5. Output Devices

Main Hardware Component Categories



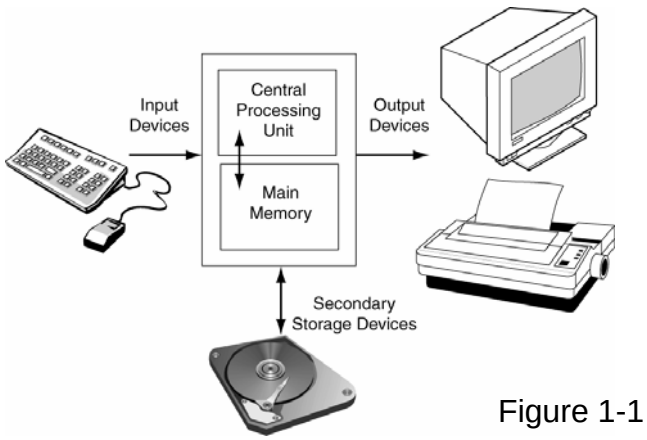
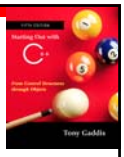


Figure 1-1

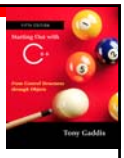
Central Processing Unit (CPU)



Comprised of:

- Control Unit
  - Retrieves and decodes program instructions
  - Coordinates activities of all other parts of computer
- Arithmetic & Logic Unit
  - Hardware optimized for high-speed numeric calculation
  - Hardware designed for true/false, yes/no decisions

CPU Organization



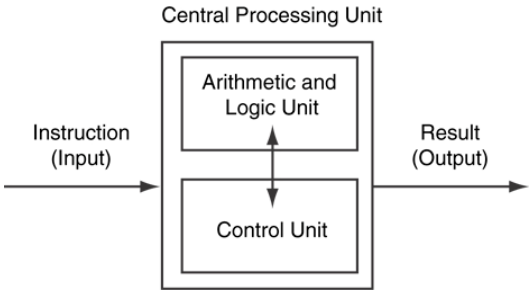
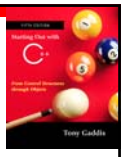


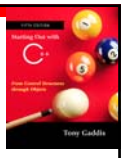
Figure 1-2

Main Memory



- It is volatile. Main memory is erased when program terminates or computer is turned off
- Also called Random Access Memory (RAM)
- Organized as follows:
  - bit: smallest piece of memory. Has values 0 (off, false) or 1 (on, true)
  - byte: 8 consecutive bits. Bytes have addresses.
- Addresses – Each byte in memory is identified by a unique number known as an *address*.

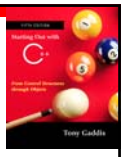
Main Memory



0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16 149	17	18	19
20	21	22	23 72	24	25	26	27	28	29

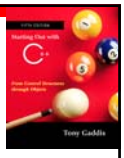
In Figure 1-3, the number 149 is stored in the byte with the address 16, and the number 72 is stored at address 23.

Secondary Storage



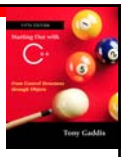
- Non-volatile: data retained when program is not running or computer is turned off
- Comes in a variety of media:
  - magnetic: floppy disk, zip disk, hard drive
  - optical: CD-ROM
  - Flash drives, connected to the USB port

Input Devices



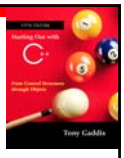
- Devices that send information to the computer from outside
- Many devices can provide input:
  - Keyboard, mouse, scanner, digital camera, microphone
  - Disk drives and CD-ROM

Output Devices

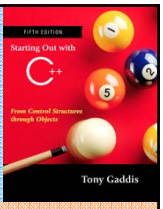


- Output is information sent from a computer program to the outside world.
- The output is sent to an output device
- Many devices can be used for output:
  - Computer monitor and printer
  - Floppy, zip disk drives
  - Writable CD drives

Software – Programs That Run on a Computer

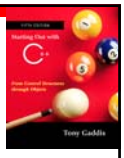


- Categories of software:
  - Operating system: programs that manage the computer hardware and the programs that run on them. *Examples*: Windows, UNIX, Linux
  - Application software: programs that provide services to the user. *Examples* : word processing, games, programs to solve specific problems



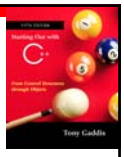
1.3 Programs and Programming Languages

Programs and Programming Languages



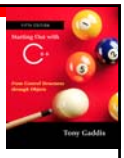
- A program is a set of instructions that the computer follows to perform a task
- We start with an *algorithm*, which is a set of well-defined steps.

Example Algorithm for Calculating Gross Pay



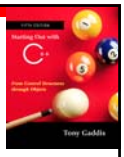
1. Display a message on the screen asking "How many hours did you work?"
2. Wait for the user to enter the number of hours worked. Once the user enters a number, store it in memory.
3. Display a message on the screen asking "How much do you get paid per hour?"
4. Wait for the user to enter an hourly pay rate. Once the user enters a number, store it in memory.
5. Multiply the number of hours by the amount paid per hour, and store the result in memory.
6. Display a message on the screen that tells the amount of money earned. The message must include the result of the calculation performed in Step 5.

Machine Language



- Although the previous algorithm defines the steps for calculating the gross pay, it is not ready to be executed on the computer.
- The computer only executes *machine language* instructions.

Machine Language

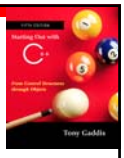


- Machine language instructions are binary numbers, such as

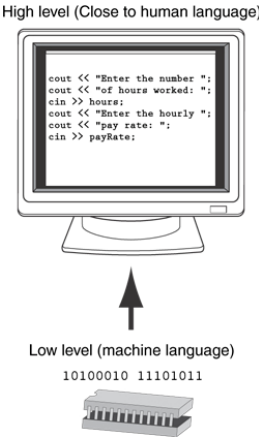
```
1011010000000101
```

- Rather than writing programs in machine language, programmers use *programming languages*.

Programs and Programming Languages



- Types of languages:
  - Low-level: used for communication with computer hardware directly. Often written in binary machine code (0's/1's) directly.
  - High-level: closer to human language



Some Well-Known Programming Languages

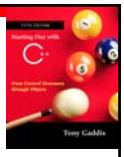
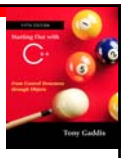


Table 1-1

Language	Description
BASIC	Beginners All-purpose Symbolic Instruction Code. A general programming language originally designed to be simple enough for beginners to learn.
FORTRAN	Formula Translator. A language designed for programming complex mathematical algorithms.
COBOL	Common Business-Oriented Language. A language designed for business applications.
Pascal	A structured, general-purpose language designed primarily for teaching programming.
C	A structured, general-purpose language developed at Bell Laboratories. C offers both high-level and low-level features.
C++	Based on the C language, C++ offers object-oriented features not found in C. Also invented at Bell Laboratories.
C#	Pronounced "C sharp." A language invented by Microsoft for developing applications based on the Microsoft .NET platform.
Java	An object-oriented language invented at Sun Microsystems. Java may be used to develop programs that run over the Internet, in a Web browser.
Visual Basic	A Microsoft programming language and software development environment that allows programmers to quickly create Windows-based applications.

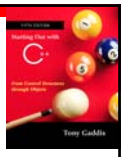
From a High-level Program to an Executable File

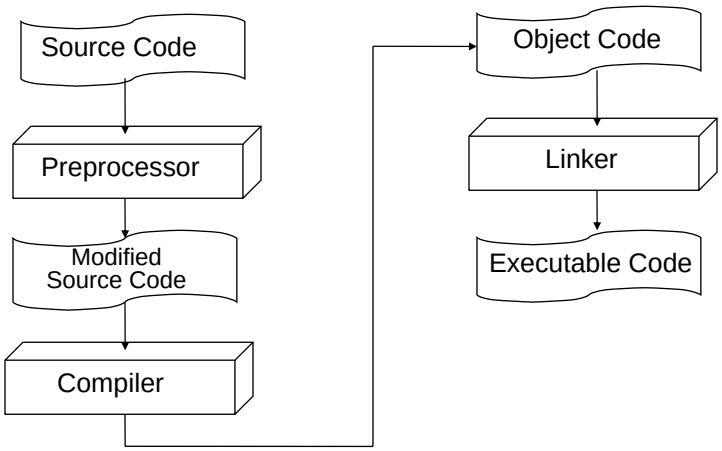


a) Create file containing the program with a text editor.
b) Run preprocessor to convert source file directives to source code program statements.
c) Run compiler to convert source program into machine instructions.
d) Run linker to connect hardware-specific code to machine instructions, producing an executable file.

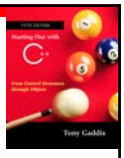
- Steps b–d are often performed by a single command or button click.
- Errors detected at any step will prevent execution of following steps.

From a High-level Program to an Executable File



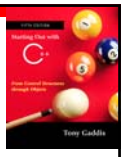


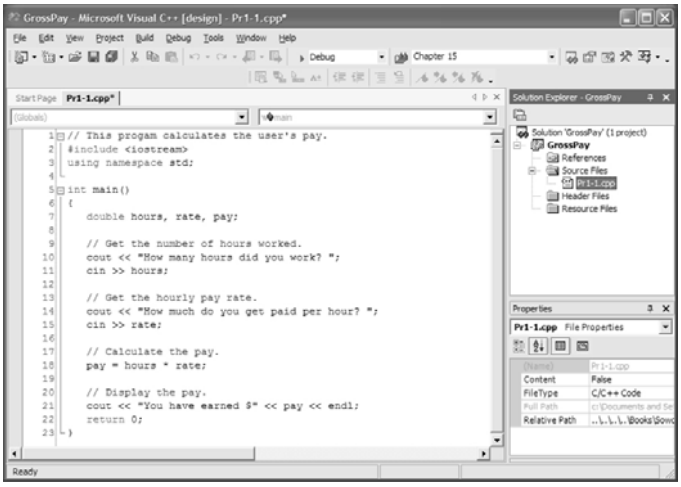
Integrated Development Environments (IDEs)

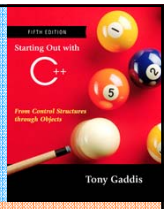


- An integrated development environment, or IDE, combine all the tools needed to write, compile, and debug a program into a single software application.
- Examples are Microsoft Visual C++, Borland C++ Builder, CodeWarrior, etc.

Integrated Development Environments (IDEs)

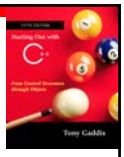






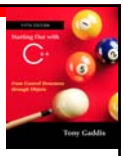
1.4 What Is a Program Made Of?

What Is a Program Made Of?



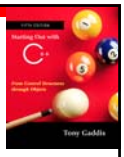
- Common elements in programming languages:
  - Key Words
  - Programmer-Defined Identifiers
  - Operators
  - Punctuation
  - Syntax

Program 1-1



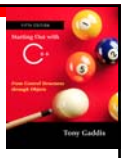
```
 1  // This program calculates the user's pay.
 2  #include <iostream>
 3  using namespace std;
 4
 5  int main()
 6  {
 7     double hours, rate, pay;
 8
 9     // Get the number of hours worked.
10     cout << "How many hours did you work? ";
11     cin >> hours;
12
13     // Get the hourly pay rate.
14     cout << "How much do you get paid per hour? ";
15     cin >> rate;
16
17     // Calculate the pay.
18     pay = hours * rate;
19
20     // Display the pay.
21     cout << "You have earned $" << pay << endl;
22     return 0;
23  }
```

Key Words



- Also known as reserved words
- Have a special meaning in C++
- Can not be used for any other purpose
- Key words in the Program 1-1: `using`, `namespace`, `int`, `main`, `double`, and `return`.

Key Words



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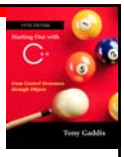
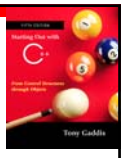
Programmer-Defined Identifiers



- Names made up by the programmer
- Not part of the C++ language
- Used to represent various things: variables (memory locations), functions, etc.
- In Program 1-1: `hours`, `rate`, and `pay`.

Programmer-Defined Identifiers



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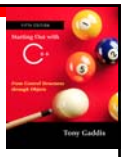
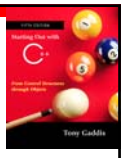
Operators



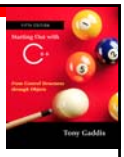
- Used to perform operations on data
- Many types of operators:
  - Arithmetic - ex: `+, -, *, /`
  - Assignment – ex: =
- Some operators in Program1-1:
  `<<  >>  =  *`

Operators



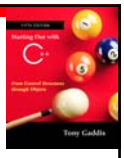
```
 1  // This program calculates the user's pay.
 2  #include <iostream>
 3  using namespace std;
 4
 5  int main()
 6  {
 7     double hours, rate, pay;
 8
 9     // Get the number of hours worked.
10     cout << "How many hours did you work? ";
11     cin >> hours;
12
13     // Get the hourly pay rate.
14     cout << "How much do you get paid per hour? ";
15     cin >> rate;
16
17     // Calculate the pay.
18     pay = hours * rate;
19
20     // Display the pay.
21     cout << "You have earned $" << pay << endl;
22     return 0;
23  }
```

Punctuation



- Characters that mark the end of a statement, or that separate items in a list
- In Program 1-1: , and ;

Punctuation



```
 1  // This program calculates the user's pay.
 2  #include <iostream>
 3  using namespace std;
 4
 5  int main()
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 8
 9     // Get the number of hours worked.
10     cout << "How many hours did you work? ";
11     cin >> hours;
12
13     // Get the hourly pay rate.
14     cout << "How much do you get paid per hour? ";
15     cin >> rate;
16
17     // Calculate the pay.
18     pay = hours * rate;
19
20     // Display the pay.
21     cout << "You have earned $" << pay << endl;
22     return 0;
23  }
```
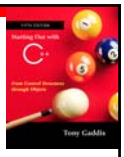
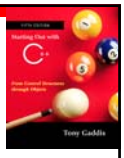

Syntax



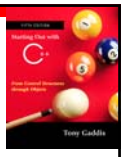
- The rules of grammar that must be followed when writing a program
- Controls the use of key words, operators, programmer-defined symbols, and punctuation

Variables



- A variable is a named storage location in the computer's memory for holding a piece of data.
- In Program 1-1 we used three variables:
  - The **`hours`** variable was used to hold the hours worked
  - The **`rate`** variable was used to hold the pay rate
  - The **`pay`** variable was used to hold the gross pay

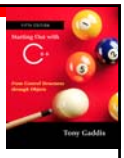
Variable Definitions



- To create a variable in a program you must write a variable definition (also called a variable declaration)
- Here is the statement from Program 1-1 that defines the variables:

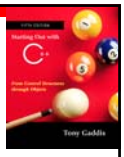
```
double hours, rate, pay;
```


Variable Definitions



- There are many different types of data, which you will learn about in this course.
- A variable holds a specific type of data.
- The variable definition specifies the type of data a variable can hold, and the variable name.

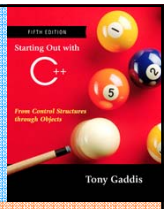
Variable Definitions



- Once again, line 7 from Program 1-1:

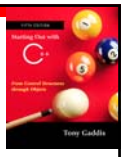
```
double hours, rate, pay;
```

- The word **`double`** specifies that the variables can hold double-precision floating point numbers. (You will learn more about that in Chapter 2)



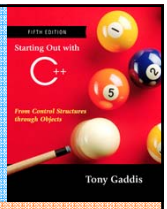
1.5 Input, Processing, and Output

Input, Processing, and Output



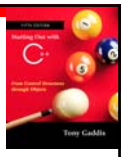
Three steps that a program typically performs:

1) **Gather input data:**
   - from keyboard
   - from files on disk drives
2) **Process the input data**
3) **Display the results as output:**
   - send it to the screen
   - write to a file



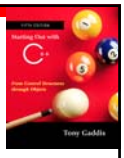
1.6 The Programming Process

The Programming Process



1. Clearly define what the program is to do.
2. Visualize the program running on the computer.
3. Use design tools such as a hierarchy chart, flowcharts, or pseudocode to create a model of the program.
4. Check the model for logical errors.
5. Type the code, save it, and compile it.
6. Correct any errors found during compilation. Repeat Steps 5 and 6 as many times as necessary.
7. Run the program with test data for input.
8. Correct any errors found while running the program. Repeat Steps 5 through 8 as many times as necessary.
9. Validate the results of the program.

Algorithm: Formal Definition

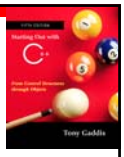


(noun) a well-ordered collection of unambiguous and effectively computable operations that, when executed, produces a result and halts in a finite amount of time.

Compared with the informal definition:

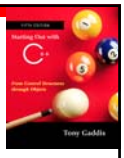
(noun) A procedure for solving a mathematical problem in a finite number of steps that frequently involves repetition of an operation

Why algorithms?



- **Reason #1:** If we can specify an algorithm to solve a problem, we can automate its solution
- **Reason #2:** Algorithmic solutions can be encoded into an appropriate language and given to the computing agent
  - The agent can be a person, desktop system, appliance, robot, etc.
  - The agent does not need to understand
    - Creative processes that went into discovery of solution
    - Principles and concepts that underlie the problem
- **Reason #3:** Algorithmic solutions can be analyzed for correctness and efficiency

Representing Algorithms

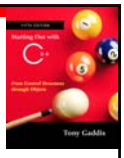


- Natural language
  - Language spoken and written in everyday life
  - Examples: English, Spanish, Arabic, etc.
  - Problems with using natural language for algorithms
    - Verbose
    - Imprecise
    - Relies on context and experiences to give precise meaning to a word or phrase

Addition Algorithm in English

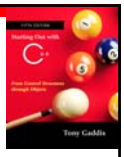
Initially, set the value of the variable *carry* to 0 and the value of the variable *i* to 0. When these initializations have been completed, begin looping as long as the value of the variable *i* is less than or equal to $(m - 1)$. First, add together the values of the two digits a_i and b_i and the current value of the carry digit to get the result called c_i. Now check the value of c_i to see whether it is greater than or equal to 10. If c_i is greater than or equal to 10, then reset the value of *carry* to 1 and reduce the value of c_i by 10; otherwise, set the value of *carry* to zero. When you are done with that operation, add 1 to *i* and begin the loop all over again. When the loop has completed execution, set the leftmost digit of the result c_m to the value of *carry* and print out the final result, which consists of the digits $c_m\, c_m - 1 \ldots c_0$. After printing the result, the algorithm is finished, and it terminates.

Representing Algorithms



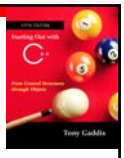
- High-level programming language
  - Examples: C++, Java
  - Problem with using a high-level programming language for algorithms
    - During the initial phases of design, we are forced to deal with detailed language issues

A C++ Program for Addition



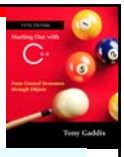
```
{
int i, m, Carry;
int[] a = new int[100];
int[] b = new int[100];
int[] c = new int[100];
m = Console.readInt();
for (int j = 0; j < =m-1; j++)   {
         a[j] = Console.readInt();
         b[j] = Console.readInt();
}
Carry = 0;
i = 0;
while (i < m)   {
         c[i] = a[i] + b[i] + Carry;
         if (c[i] > =10)
         .
         .
         .
```


Characteristics of Pseudocode



- English language constructs modeled to look like statements available in most programming languages
  - Easy to Learn
- Steps presented in a structured manner (numbered, indented, etc.)
  - Easy to follow
- No fixed syntax for most operations is required
  - Less restrictive than a programming language
- Less ambiguous and more readable than natural language
- Emphasis is on process, not notation
  - The logic of the solution is what to focus on, not choice of “words”
- Can be easily translated into a programming language

Pseudocode Summary



COMPUTATION:

Set the value of "variable" to "arithmetic expression"

INPUT/OUTPUT:

Get a value for "variable", "variable"...
Print the value of "variable", "variable", ...
Print the message 'message'

CONDITIONAL:

If "a true/false condition" is true then
    first set of algorithmic operations
Else
    second set of algorithmic operations

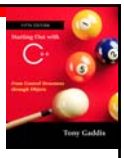
ITERATIVE:

While ("a true/false condition") do step *i* through step *j*
    Step *i:* operation
    .
    .
    .
    Step *j:* operation

While ("a true/false condition") do
    operation
    .
    .
    .
    operation
End of the loop

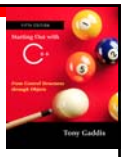
Do
    operation
    operation
    .
    .
    .
While ("a true/false condition")

Classes of Operations



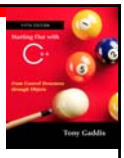
- Types of algorithmic operations
  - Sequential Operations : performed in step-by-step fashion
    - Setting Values
    - Mathematical Expressions
    - Input/Output Statements
  - Conditional Operations: allows your logic to have different paths
    - Decision making steps
    - If "something" then do "it" otherwise do "the other thing"
  - Iterative/Repetitive Operations
    - Used for repeating a group of operations over and over
- An algorithm is a collection of operations these classes

Sequential Operations



- Computation operations
  - Example
    - **Set the value** of ***variable*** to *text/arithmetic expression*
    - **Set the value** of *Name* to "Charles"
    - **Set the value** of *Age* to 17+5
- Input operations
  - To receive data values from the outside world
  - Example
    - **Get a value** for *r*, the radius of the circle
- Output operations
  - To send results to the outside world for display
  - Example
    - **Print the value** of *Area*

Algorithm: Average Miles Per Gallon

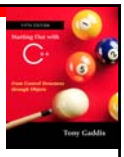


1. **Get values** for *gallons used*, *starting mileage*, and *ending mileage*
2. **Set value** of *distance driven* to (*ending mileage - starting mileage*)
3. **Set value** of *average miles per gallon* to (*distance driven / gallons used*)
4. **Print the value** of *average miles per gallon*
5. **Stop**

What are the variables?

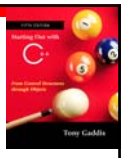
What are the input variables?

What are the output variables?



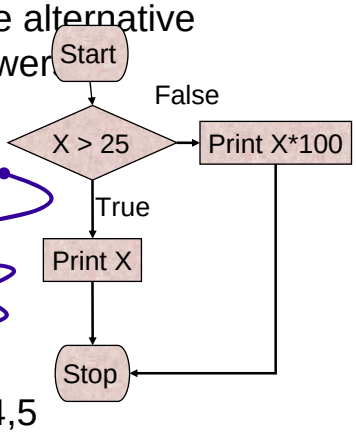
Control Operations

- Control operations change the ***path of execution***
  - The path of execution is the list of steps executed from beginning to end
  - In a sequential algorithm, every step is executed in the listed order from start to finish
  - The execution path of the previous algorithm would be:
    - Steps 1, 2, 3, 4, and 5
- Classes of Control Operations
  - Conditional operations
    - Create multiple execution paths
  - Iterative operations
    - Repeat an execution path (subpath) more than once

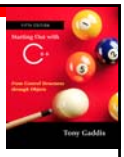


Conditional Operations

- Conditional operations
  - Ask questions and choose alternative actions based on the answer
  - Example
    1. if ***x*** is greater than 25 then
    2. print ***x***
    3. else
    4. print ***x*** * 100
    5. Stop
  - Paths are: 1,2,5 and 1,3,4,5



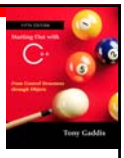
Algorithm: Average Miles Per Gallon (Version 2)



1. **Get values** for *gallons used*, *starting mileage*, and *ending mileage*
2. **Set value** of *distance driven* to (*ending mileage* - *starting mileage*)
3. **Set value** of *average miles per gallon* to (*distance driven* / *gallons used*)
4. **Print the value** of *average miles per gallon*
5. **if** *average miles per gallon* is greater than 25.0 **then**
6. **Print** the message "You are getting good gas mileage"
7. **Else**
8. **Print** the message "You are NOT getting good gas mileage"
9. **STOP**

How many paths does this algorithm have? What are they?

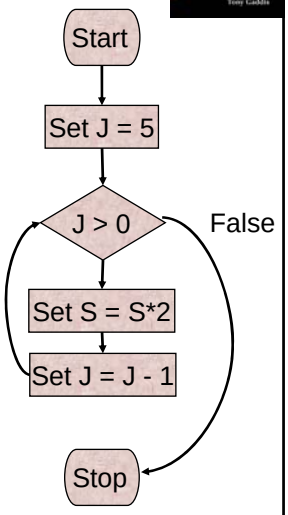
Iterative/Repetitive Operations



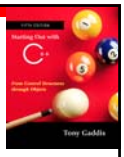
- Iterative/Repetitive operations
  - Perform "looping" behavior; repeating actions until a continuation condition becomes false
  - Sometime called a Loop
  - Examples

```
1.set j to 5
2.while j > 0 do
3.     set s to s * 2
4.     set j to j - 1
5.end while
6.stop
```

  - Execution Path is 1, 2, 3,4,3,4,3,4…5,6 until J <= 0
  - Continuation condition
    - Condition that determines if the loop keeps going
  - Loop body
    - The statements that are repeated

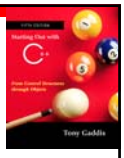


Algorithm: Average Miles Per Gallon (Version 3)



1. **Set** the value of response to Yes
2. **While** response is equal to Yes do steps 3 - 12
3. **Get values** for *gallons used*, *starting mileage*, and *ending mileage*
4. **Set value** of *distance driven* to (*ending mileage - starting mileage*)
5. **Set value** of *average miles per gallon* to (*distance driven / gallons used*)
6. **Print the value** of *average miles per gallon*
7. **if** *average miles per gallon* is greater than 25.0 **then**
8. **Print** the message "You are getting good gas mileage"
9. **Else**
10. **Print** the message "You are NOT getting good gas mileage"
11. **Print** the message "Do you want to do this again? (enter yes or no)"
12. **Get** value of response from the user
13. **STOP**

The Programming Process Recap



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2. Visualize the program running on the computer.
3. Use design tools such as a hierarchy chart, flowcharts, or pseudocode to create a model of the program.
4. Check the model for logical errors.
5. Type the code, save it, and compile it.
6. Correct any errors found during compilation. Repeat Steps 5 and 6 as many times as necessary.
7. Run the program with test data for input.
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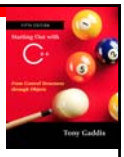
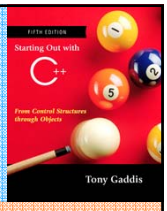
9. Validate the results of the program.

An Example

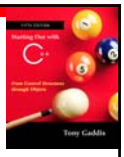


- Write an algorithm that gets N numbers, computes the average of those N numbers, and prints out the average.
  - Analysis
    - What are the inputs?
    - What are the outputs?
    - What are the formulas/processes you have to do to solve this by hand?
    - Are there any special conditions?
  - Design
    - Write the algorithm
  - Test
    - Perform table trace
  - Implement in C++ (by the professor)



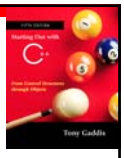
1.7 Procedural and Object-Oriented Programming

Procedural and Object-Oriented Programming



- Procedural programming: focus is on the process. Procedures/functions are written to process data.
- Object-Oriented programming: focus is on objects, which contain data and the means to manipulate the data. Messages sent to objects to perform operations.

Lets Construct Solutions



1) Write an algorithm that computes the area of a circle.
2) Write an algorithm that takes the prices of 3 items and computes the subtotal and total with 8% tax.
3) Write an algorithm that finds the maximum of 3 input values.
4) Write an algorithm that that can find the maximum of N values.
5) Write an algorithm that finds the sum and product of N values.