Chapter 3 - Structured Program Development

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3.1 Introduction

- Before writing a program:
  - Have a thorough understanding of the problem
  - Carefully plan an approach for solving it
- While writing a program:
  - Know what “building blocks” are available
  - Use good programming principles

3.2 Algorithms

- Computing problems
  - All can be solved by executing a series of actions in a specific order
- Algorithm: procedure in terms of
  - Actions to be executed
  - The order in which these actions are to be executed
- Program control
  - Specify order in which statements are to executed

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3.3 Pseudocode

- Pseudocode
  - Artificial, informal language that helps us develop algorithms
  - Similar to everyday English
  - Not actually executed on computers
  - Helps us “think out” a program before writing it
    - Easy to convert into a corresponding C program
    - Consists only of executable statements

3.4 Control Structures

- Sequential execution
  - Statements executed one after the other in the order written
- Transfer of control
  - When the next statement executed is not the next one in sequence
  - Overuse of **`goto`** statements led to many problems
- Bohm and Jacopini
  - All programs written in terms of 3 control structures
    - Sequence structures: Built into C. Programs executed sequentially by default
    - Selection structures: C has three types: **`if`**, **`if`**/**`else`**, and **`switch`**
    - Repetition structures: C has three types: **`while`**, **`do`**/**`while`** and **`for`**

3.4 Control Structures

- Flowchart
  - Graphical representation of an algorithm
  - Drawn using certain special-purpose symbols connected by arrows called flowlines
  - Rectangle symbol (action symbol):
    - Indicates any type of action
  - Diamond symbol:
    - Check condition
  - Oval symbol:
    - Indicates the beginning or end of a program or a section of code
- Single-entry/single-exit control structures
  - Connect exit point of one control structure to entry point of the next (control-structure stacking)
  - Makes programs easy to build

3.5 The `if` Selection Structure

- Selection structure:
  - Used to choose among alternative courses of action
  - Pseudocode:

```
If student's grade is greater than or equal to 60
   Print "Passed"
```

- If condition **`true`**
  - Print statement executed and program goes on to next statement
  - If **`false`**, print statement is ignored and the program goes onto the next statement
  - Indenting makes programs easier to read
    - C ignores whitespace characters

3.5 The `if` Selection Structure

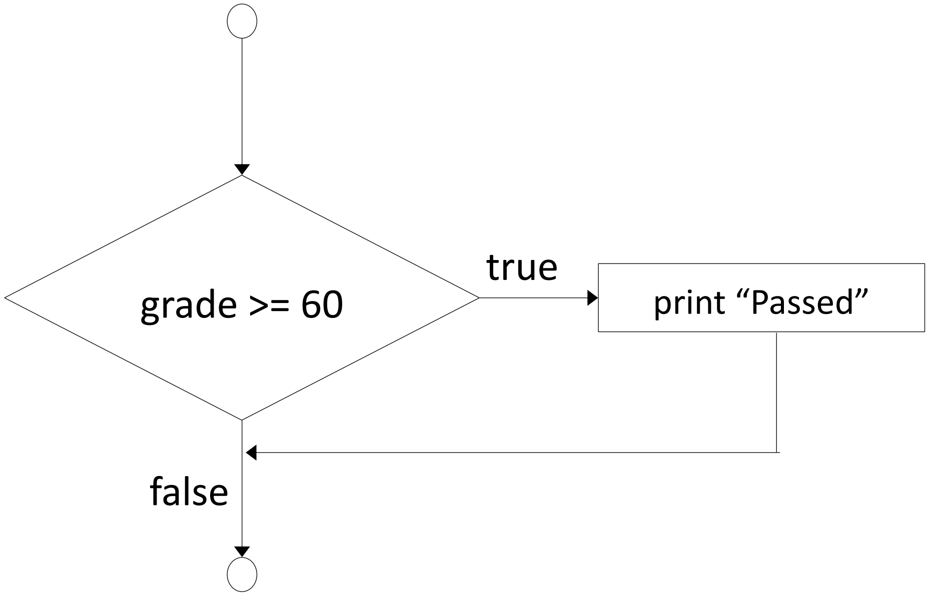
- Translate Pseudocode statement into C:

```
if ( grade >= 60 )
   printf( "Passed\n" );
```

  - C code corresponds closely to the pseudocode
- Diamond symbol (decision symbol)
  - Indicates decision is to be made
  - Contains an expression that can be **`true`** or **`false`**
  - Test the condition, follow appropriate path

3.5 The `if` Selection Structure

- **`if`** structure is a single-entry/single-exit structure



A decision can be made on any expression.

zero - **`false`**

nonzero - **`true`**

Example:

`3 - 4` is **`true`**

3.6 The `if/else` Selection Structure

- **`if`**
  - Only performs an action if the condition is **`true`**
- **`if/else`**
  - Specifies an action to be performed both when the condition is **`true`** and when it is **`false`**
- Psuedocode:

```
If student's grade is greater than or equal to 60
   Print "Passed"
else
   Print "Failed"
```

  - Note spacing/indentation conventions

3.6 The `if/else` Selection Structure

- C code:

```
if ( grade >= 60 )
   printf( "Passed\n");
else
   printf( "Failed\n");
```

- Ternary conditional operator (`?:`)
  - Takes three arguments (condition, value if **`true`**, value if **`false`**)
  - Our pseudocode could be written:

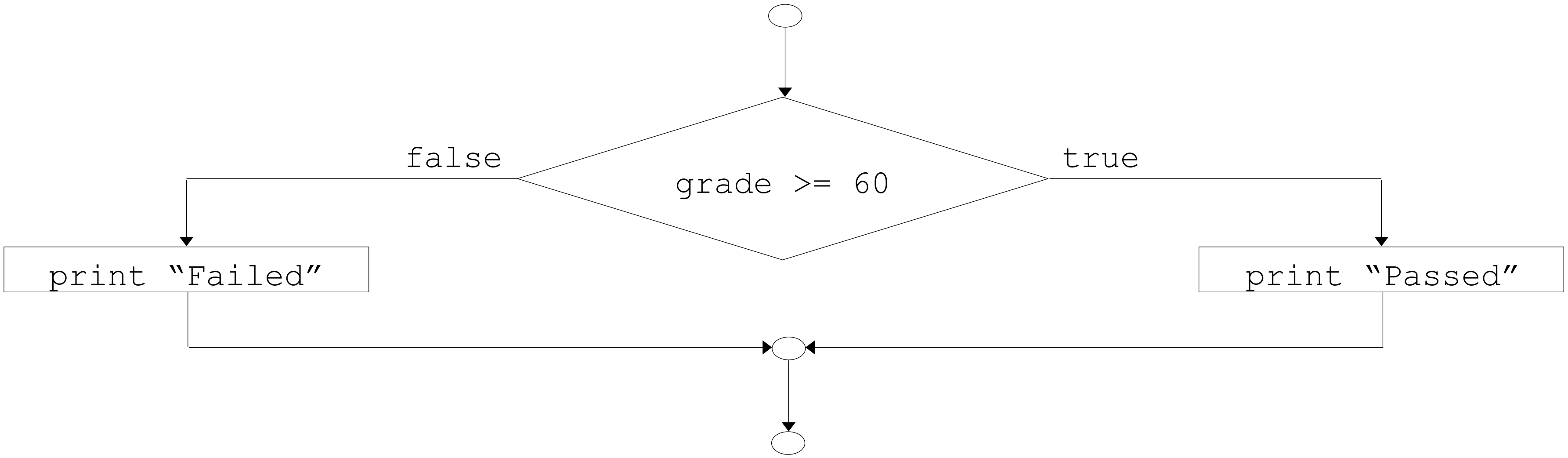
```
printf( "%s\n", grade >= 60 ? "Passed" :
  "Failed" );
```

  - Or it could have been written:

```
grade >= 60 ? printf( “Passed\n” ) :
 printf( “Failed\n” );
```

3.6 The `if/else` Selection Structure

- Flow chart of the **`if/else`** selection structure



- Nested **`if/else`** structures
  - Test for multiple cases by placing **`if/else`** selection structures inside **`if/else`** selection structures
  - Once condition is met, rest of statements skipped
  - Deep indentation usually not used in practice

3.6 The **if/else** Selection Structure

– Pseudocode for a nested **if**/**else** structure

```
If student’s grade is greater than or equal to 90
  Print “A”
else
  If student’s grade is greater than or equal to 80
    Print “B”
  else
    If student’s grade is greater than or equal to 70
      Print “C”
    else
      If student’s grade is greater than or equal to 60
        Print “D”
      else
        Print “F”
```

3.6 The if/else Selection Structure

- Compound statement:
  - Set of statements within a pair of braces
  - Example:

```
if ( grade >= 60 )
   printf( "Passed.\n" );
else {
   printf( "Failed.\n" );
   printf( "You must take this course
      again.\n" );
 }
```

  - Without the braces, the statement

```
printf("You must take this course
   again.\n");
```

would be executed automatically

3.6 The if/else Selection Structure

- Block:
  - Compound statements with declarations
- Syntax errors
  - Caught by compiler
- Logic errors:
  - Have their effect at execution time
  - Non-fatal: program runs, but has incorrect output
  - Fatal: program exits prematurely

3.7 The `while` Repetition Structure

- Repetition structure
  - Programmer specifies an action to be repeated while some condition remains **`true`**
  - Psuedocode:

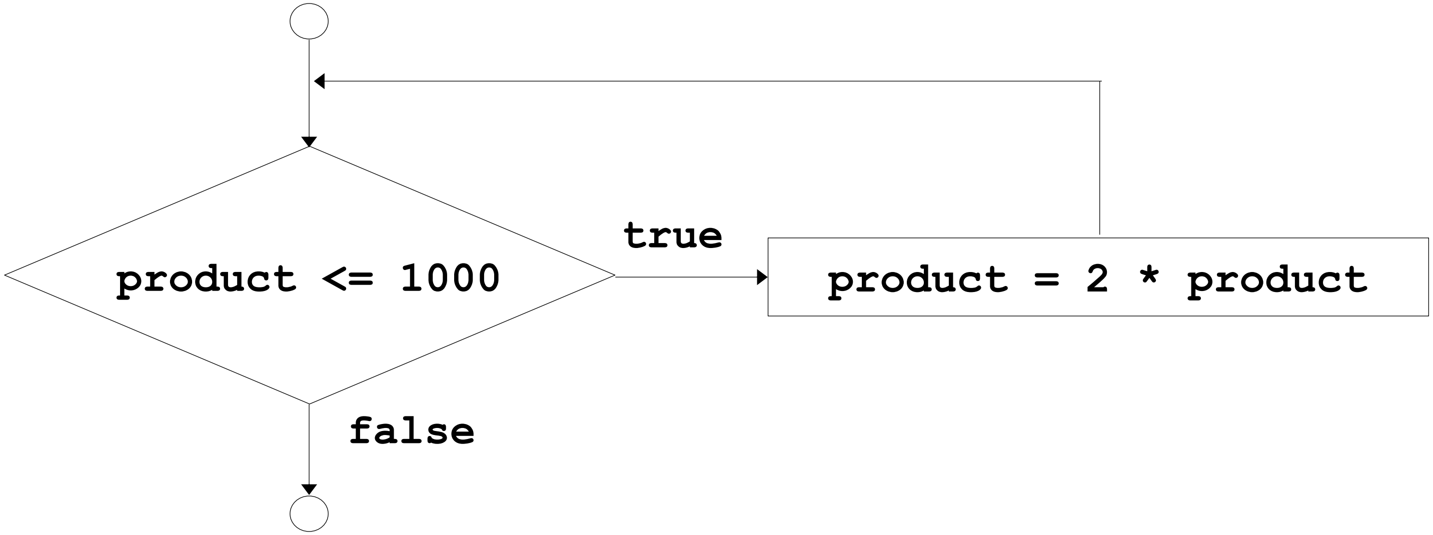
```
While there are more items on my shopping list
   Purchase next item and cross it off my list
```

  - **`while`** loop repeated until condition becomes **`false`**

3.7 The while Repetition Structure

- Example:

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



3.8 Formulating Algorithms (Counter-Controlled Repetition)

- Counter-controlled repetition
  - Loop repeated until counter reaches a certain value
  - Definite repetition: number of repetitions is known
  - Example: A class of ten students took a quiz. The grades (integers in the range 0 to 100) for this quiz are available to you. Determine the class average on the quiz
  - Pseudocode:

```
Set total to zero
   Set grade counter to one

While grade counter is less than or equal to ten
   Input the next grade
   Add the grade into the total
   Add one to the grade counter

Set the class average to the total divided by ten
   Print the class average
```

```c
/* Fig. 3.6: fig03_06.c
   Class average program with
   counter-controlled repetition */
#include <stdio.h>

int main()
{
   int counter, grade, total, average;

   /* initialization phase */
   total = 0;
   counter = 1;

   /* processing phase */
   while ( counter <= 10 ) {
      printf( "Enter grade: " );
      scanf( "%d", &grade );
      total = total + grade;
      counter = counter + 1;
   }

   /* termination phase */
   average = total / 10;
   printf( "Class average is %d\n", average );

   return 0;   /* indicate program ended successfully */
}
```

Outline

1. **Initialize Variables**
2. **Execute Loop**
3. **Output results**

Program Output

```
Enter grade: 98
Enter grade: 76
Enter grade: 71
Enter grade: 87
Enter grade: 83
Enter grade: 90
Enter grade: 57
Enter grade: 79
Enter grade: 82
Enter grade: 94
Class average is 81
```

3.9 Formulating Algorithms with Top-Down, Stepwise Refinement

- Problem becomes:

  Develop a class-averaging program that will process an arbitrary number of grades each time the program is run.

  – Unknown number of students

  – How will the program know to end?

- Use sentinel value

  – Also called signal value, dummy value, or flag value

  – Indicates "end of data entry."

  – Loop ends when user inputs the sentinel value

  – Sentinel value chosen so it cannot be confused with a regular input (such as **`-1`** in this case)

3.9 Formulating Algorithms with Top-Down, Stepwise Refinement

- Top-down, stepwise refinement
  - Begin with a pseudocode representation of the *top*:

```
Determine the class average for the quiz
```

  - Divide *top* into smaller tasks and list them in order:

```
Initialize variables
Input, sum and count the quiz grades
Calculate and print the class average
```

- Many programs have three phases:
  - Initialization: initializes the program variables
  - Processing: inputs data values and adjusts program variables accordingly
  - Termination: calculates and prints the final results

3.9 Formulating Algorithms with Top-Down, Stepwise Refinement

- Refine the initialization phase from *Initialize variables* to:

```
Initialize total to zero
Initialize counter to zero
```

- Refine *Input, sum and count the quiz grades* to

```
Input the first grade (possibly the sentinel)
While the user has not as yet entered the sentinel
    Add this grade into the running total
    Add one to the grade counter
    Input the next grade (possibly the sentinel)
```

3.9 Formulating Algorithms with Top-Down, Stepwise Refinement

- Refine *Calculate and print the class average* to

```
If the counter is not equal to zero
    Set the average to the total divided by the counter
    Print the average
else
    Print "No grades were entered"
```

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```c
/* Fig. 3.8: fig03_08.c
   Class average program with
   sentinel-controlled repetition */
#include <stdio.h>

int main()
{
   float average;              /* new data type */
   int counter, grade, total;

   /* initialization phase */
   total = 0;
   counter = 0;

   /* processing phase */
   printf( "Enter grade, -1 to end: " );
   scanf( "%d", &grade );

   while ( grade != -1 ) {
      total = total + grade;
      counter = counter + 1;
      printf( "Enter grade, -1 to end: " );
      scanf( "%d", &grade );
   }
```

Outline

1. Initialize Variables

2. Get user input

2.1 Perform Loop

```

   /* termination phase */
   if ( counter != 0 ) {
      average = ( float ) total / counter;
      printf( "Class average is %.2f", average );
   }
   else
      printf( "No grades were entered\n" );

   return 0;   /* indicate program ended successfully */
}
```

3. Calculate Average

3.1 Print Results

```
Enter grade, -1 to end: 75
Enter grade, -1 to end: 94
Enter grade, -1 to end: 97
Enter grade, -1 to end: 88
Enter grade, -1 to end: 70
Enter grade, -1 to end: 64
Enter grade, -1 to end: 83
Enter grade, -1 to end: 89
Enter grade, -1 to end: -1
Class average is 82.50
```

Program Output

3.10 Nested control structures

- Problem
  - A college has a list of test results (**`1`** = pass, **`2`** = fail) for 10 students
  - Write a program that analyzes the results
    - If more than 8 students pass, print "Raise Tuition"
- Notice that
  - The program must process 10 test results
    - Counter-controlled loop will be used
  - Two counters can be used
    - One for number of passes, one for number of fails
  - Each test result is a number—either a **`1`** or a **`2`**
    - If the number is not a **`1`**, we assume that it is a **`2`**

3.10 Nested control structures

- Top level outline

```
    Analyze exam results and decide if tuition should be raised
```

- First Refinement

```
    Initialize variables
    Input the ten quiz grades and count passes and failures
    Print a summary of the exam results and decide if tuition should
       be raised
```

- Refine *Initialize variables* to

```
    Initialize passes to zero
    Initialize failures to zero
    Initialize student counter to one
```

3.10 Nested control structures

- Refine *Input the ten quiz grades and count passes and failures* to

```
While student counter is less than or equal to ten
    Input the next exam result
    If the student passed
        Add one to passes
    else
        Add one to failures
    Add one to student counter
```

- Refine *Print a summary of the exam results and decide if tuition should be raised* to

```
Print the number of passes
Print the number of failures
If more than eight students passed
    Print "Raise tuition"
```

```c
/* Fig. 3.10: fig03_10.c
   Analysis of examination results */
#include <stdio.h>

int main()
{
   /* initializing variables in declarations */
   int passes = 0, failures = 0, student = 1, result;

   /* process 10 students; counter-controlled loop */
   while ( student <= 10 ) {
      printf( "Enter result ( 1=pass,2=fail ): " );
      scanf( "%d", &result );

      if ( result == 1 )         /* if/else nested in while */
         passes = passes + 1;
      else
         failures = failures + 1;

      student = student + 1;
   }

   printf( "Passed %d\n", passes );
   printf( "Failed %d\n", failures );

   if ( passes > 8 )
      printf( "Raise tuition\n" );

   return 0;   /* successful termination */
}
```

Outline

1. Initialize variables

2. Input data and count passes/failures

3. Print results

Program Output

```
Enter Result (1=pass,2=fail): 1
Enter Result (1=pass,2=fail): 2
Enter Result (1=pass,2=fail): 2
Enter Result (1=pass,2=fail): 1
Enter Result (1=pass,2=fail): 1
Enter Result (1=pass,2=fail): 1
Enter Result (1=pass,2=fail): 2
Enter Result (1=pass,2=fail): 1
Enter Result (1=pass,2=fail): 1
Enter Result (1=pass,2=fail): 2
Passed 6
Failed 4
```

3.11 Assignment Operators

- Assignment operators abbreviate assignment expressions

```
c = c + 3;
```

can be abbreviated as **`c += 3;`** using the addition assignment operator

- Statements of the form

variable = *variable operator expression*;

can be rewritten as

variable **`operator=`** *expression*;

- Examples of other assignment operators:

```
d -= 4       (d = d - 4)
e *= 5       (e = e * 5)
f /= 3       (f = f / 3)
g %= 9       (g = g % 9)
```

3.12 Increment and Decrement Operators

- Increment operator (**`++`**)
  - Can be used instead of **`c+=1`**
- Decrement operator (**`--`**)
  - Can be used instead of **`c-=1`**
- Preincrement
  - Operator is used before the variable (**`++c`** or **`--c`**)
  - Variable is changed before the expression it is in is evaluated
- Postincrement
  - Operator is used after the variable (**`c++`** or **`c--`**)
  - Expression executes before the variable is changed

3.12 Increment and Decrement Operators

- If **c** equals **5**, then

  ```
  printf( "%d", ++c );
  ```

  - Prints **6**

  ```
  printf( "%d", c++ );
  ```

  - Prints **5**
  - In either case, **c** now has the value of **6**
- When variable not in an expression
  - Preincrementing and postincrementing have the same effect

  ```
  ++c;
  printf( “%d”, c );
  ```

  - Has the same effect as

  ```
  c++;
  printf( “%d”, c );
  ```