Selection Control Structures

Outline

- Boolean Expressions
- Boolean Operators
- Relational Operators
- *if – else* statement

Control Structures

- Flow of programming execution control is *sequential* unless a "control structure" is used to change that
- there are 2 general types of control structures:
  - Selection (also called branching)
  - Repetition (also called looping)

C++ control structures

- Selection
  - `if`
  - `if…else`
  - `switch`
- Repetition
  - `for` loop
  - `while` loop
  - `do…while` loop

Conditional and Logical Expressions

- Control Structures use conditional (relational) and logical (Boolean) expressions
- Conditional expressions use relational operators:

```
< <= > >= == !=
```

- Boolean expressions use logical operators:

```
! && ||
```

`bool` Data Type

- Result value from either a relational expression or Boolean expression is either `true` or `false`
- In C++, the data type `bool` is a built-in type consisting of just 2 Boolean values, the constants `true` and `false`
- we can declare (Boolean) variables of type `bool` to hold Boolean values `true` or `false`
- In C++, the value `0` represents `false` and any nonzero (`1`) represents `true`

Logical (Boolean) Expressions

A *Boolean expression* is an expression consists of

- Conditional expressions with relational operators
- a Boolean variable or constant
- Boolean expressions with Boolean operators.

Conditional expressions with relational operators

- Conditional expression is in the form

Expression1 Operator Expression2

- Examples:

```
Score1 > Score2
SideA + SideB == SideC
Length != 0
CoefB*CoefB - 4*CoefA*CoefC > 0.0
Count <= 10
Response == 'Y'
```

Relational Operators

Relational	*Description*
<	less than
<=	less than or
>	greater than
>=	greater than
==	equal to
!=	not equal to

```
temperature          >     humidity
rain                 >=    average
B * B - 4.0 * A * C  <     0.0
hours                <=    40
abs(number)          ==    35
initial              !=    'Q'
```


Example

```
int  x, y;
x = 4;
y = 6;
```

EXPRESSION	VALUE
x < y	true
x + 2 < y	false
x != y	true
x + 3 >= y	true
y == x	false
y == x+2	true
y = x	4 (true)

Boolean variable or constant

```
bool Done, Flag, Result, Test;
double Score1, Score2, Score3;
int SideA, SideB, SideC;

Done = true;
Flag = false;

Test = Score1 > Score2;
Result = SideA + SideB == SideC;

Result = Done && Flag;
```


Boolean Operators

Operator	*Description*
&&	AND
||	OR
!	NOT

AND (&&) Operator

Value of X	*Value of* Y	*Value of* X && Y
true	true	true
true	false	false
false	true	false
false	false	false

OR (||) Operator

Value of X	*Value of* Y	*Value of* X || Y
true	true	true
true	false	true
false	true	true
false	false	false

Not (!) Operator

Value of X	*Value of* !X
true	false
false	true

Precedence of Operators

Operator	*Precedence*
!	Highest precedence
* / %	↓
+ -	↓
< <= > >=	↓
== !=	↓
&&	↓
||	↓
=	Lowest precedence

Operator	Associativity
!	Right
* / %	Left
+ -	Left
<	Left
<=	Left
>	Left
>=	Left
==	Left
&&	Left
||	Left
=	Right

Examples

```
(Response=='Y') || (Response=='y')
(Count > 10) && (Response == 'Y')
!Done
```


Example

```
int  age;
bool isSenior,hasFever;
float temperature;

age = 20;
temperature = 102.0;
isSenior = (age >= 55)
hasFever = (temperature > 98.6);
```

EXPRESSION	VALUE
isSenior	false
hasFever	true
isSenior && hasFever	false
isSenior || hasFever	true
!isSenior	true
!hasFever	false

Example

```
int age, height;

age = 25;
height = 70;
```

EXPRESSION	VALUE
!(age < 10)	true
!(height > 60)	false

Example

```
int age, height;

age = 25;
height = 70;
```

EXPRESSION	VALUE
(age > 50) && (height > 60) false	false
(height > 60) || (age > 40) true	true
!(height > 60) || (age > 50) !(true) false false	false

Example

```
int age, weight;

age = 25;
weight = 145;
```

EXPRESSION	VALUE
(weight > 180) && (age >= 50) true false	false

Comparing Strings

- two objects of type string (or a string object and a C string) can be compared using the relational operators
- a character-by-character comparison is made using the ASCII character set values
- if all the characters are equal, then the 2 strings are equal. Otherwise, the string with the character with smaller ASCII value is the "lesser" string

Example

```
string   myState;
string   yourState;

myState = "Texas";
yourState = "Maryland";
```

EXPRESSION	VALUE
myState == yourState	false
myState > yourState	true
myState == "Texas"	true
myState < "texas"	true

Write an expression for each

- `taxRate` is over 25% and `income` is less than $20000
  `(taxRate > 0.25) && (income < 20000)`
- `temperature` is less than or equal to 75 or `humidity` is less than 70%
  `(temperature <= 75) || (humidity < .70)`
- `age` is over 21 and `age` is less than 60
  `(age > 21) && (age < 60)`
- `age` is 21 or 22
  `(age == 21) || (age == 22)`

WARNING about Expressions in C++

- "Boolean expression" means an expression whose value is true or false
- an expression is any valid combination of operators and operands
- each expression has a value
- this can lead to UNEXPECTED RESULTS
- construct your expressions CAREFULLY
- use of parentheses is encouraged
- otherwise, use precedence chart to determine order

What went wrong?

- This is only supposed to display "HEALTHY AIR" if the air quality index is between 50 and 80.
- But when you tested it, it displayed "HEALTHY AIR" when the index was 35.

```
int  AQIndex;
  AQIndex = 35;

  if (50 < AQIndex < 80)
        cout << "HEALTHY AIR";
```

Analysis of Situation

```
AQIndex = 35;
```

According to the precedence chart, the expression

`(50 < AQIndex < 80)` **means**

`(50 < AQIndex) < 80` **because < is Left Associative**

`(50 < AQIndex)` **is false (has value 0)**

`(0 < 80)` **is true.**

Corrected Version

```
int  AQIndex;
AQIndex = 35;

if ((50 < AQIndex) && (AQIndex < 80))
    cout << "HEALTHY AIR";
```

Comparing Real Values

- Do not compare floating point values for equality, compare them for near-equality.

```
float myNumber;
float yourNumber;

cin >> myNumber;
cin >> yourNumber;

if (fabs (myNumber - yourNumber) < 0.00001)
    cout << "They are close enough!"
         << endl;
```

Selection statements

are used to choose an action depending on the current situation in your program as it is running

Control Structure

- A *selection* statement is a control structure used to (alter the sequential flow of control) choose an action depending on the current situation in your program as it is running.
- `if-else` statement

Syntax of `if-else` Statement

```
if (Boolean expression)
    Statement1;
else
    Statement2;
```

The else part can be dropped if there is no second choice.

Expressions

Control structure use logical expressions which may include

6 Relational Operators

```
<   <=   >   >=   ==   !=
```

3 Logical Operators

```
!      &&      ||
```

What can go wrong here?

```
float   average;
float   total;
int     howMany;
   .
   .
   .
average = total / howMany;
```


Improved Version

```
float   average,
float   total;
int      howMany;

if (howMany >  0)
{
     average = total  / howMany;
     cout <<  average;
}
else
     cout << "No prices were entered";
```

Example

```
cout<<"Enter your weight";
cin>>Weight;
if (Weight < 300)
   cout<<"You are okay.";
else
   cout<<"You are over Weight.";
```

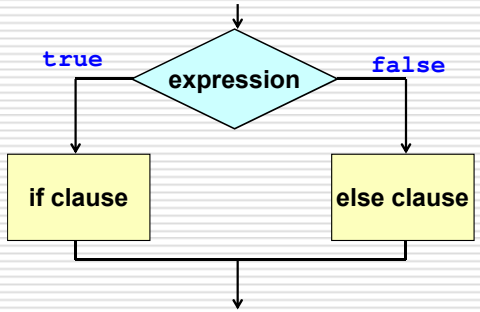
Use of blocks recommended

```
if ( Expression )
{

}
else
{

}
```

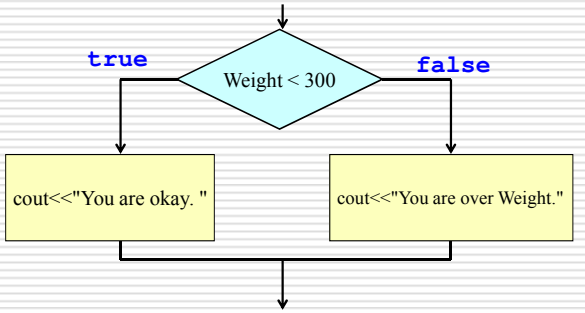
"if clause"

"else clause"

Selection Statement `if-else`



Selection Statement `if-else`



Example

```
int    carDoors, driverAge;
float  premium, monthlyPayment;
   .
   .
   .
    if ((carDoors == 4) && (driverAge > 24))
    {
        premium = 650.00 ;
        cout << " LOW RISK " ;
    }
    else
    {
        premium = 1200.00 ;
        cout << " HIGH RISK " ;
   }
monthlyPayment = premium / 12.0 + 5.00 ;
   .
   .
   .
```

What happens if you omit braces?

```
if ((carDoors == 4) && (driverAge > 24))
     premium = 650.00 ;
     cout << " LOW RISK " ;
else
     premium = 1200.00 ;
      cout << " HIGH RISK " ;

monthlyPayment = premium / 12.0 + 5.00 ;
```

- COMPILE ERROR OCCURS. The "if clause" is the single statement following the if.

Single statement in if and else clause

Braces can only be omitted when each clause is a single statement

```
if  (lastInitial  <= 'K')
    volume = 1;
else
    volume = 2;

cout << "Look it up in volume # "
     <<volume <<  " of NYC phone book";
```


Example

- Assign value .25 to `discountRate` and assign value 10.00 to `shipCost` if `purchase` is over 100.00
- Otherwise, assign value .15 to `discountRate` and assign value 5.00 to `shipCost`
- Either way, calculate totalBill

Code for Example

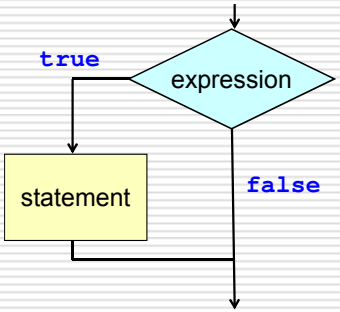
```
if (purchase > 100.00)
{
  discountRate  = 0.25;
    shipCost    =  10.00;
}
else
{
    discountRate  = 0.15 ;
    shipCost    =  5.00 ;
}
totalBill = purchase *(1.0 - discountRate)+ shipCost;
```

if Syntax

```
if (Boolean expression)
    Statement1;
```

- NOTE: Statement can be a single statement, a null statement, or a block.

Selection Statement if



Example

```
cout<<"Enter a number";
cin>>Number;
if  (Number < 0)
{
   cout<<"The number that you enter is
   negative.";
   cout<<"\nEnter another number.";
   cin>>Number;
}
```


Terminating your program

```
int number ;

cout << "Enter a non-zero number ";
cin  >> number;

if  (number == 0)
{
   cout << "Bad input. Program terminated ";
   return 1;
}
// otherwise continue processing
```

Write `if` or `if-else`

- If `taxCode` is 'T', increase price by adding `taxRate` times `price` to it.

```
if (taxCode == 'T')
    price = price + taxRate * price;
```

- If `code` has value 1, read values for income and `taxRate` from `myInfile`, and calculate and display `taxDue` as their product.

```
if (code == 1)
{
   myInfile >> income >> taxRate;
   taxDue = income * taxRate;
   cout << taxDue;
}
```

- If `A` is strictly between 0 and 5, set `B` equal to 1/A, otherwise set `B` equal to `A`.

```
if (( A > 0 ) && (A < 5))
   B = 1/A;
else
   B = A;
```


What output? and Why?

```
int age;

age = 20;

if (age = 16)
{
   cout << "Did you get driver's license?";
}
```


What output? and Why?

```
int age;

age = 30;

if (age < 18)
{
   cout << "Do you drive?";
   cout << "Too young to vote";
}
```


These are equivalent. Why?

```
if  (number == 0)      if  (! number )
{                      {
    .                      .
    .                      .
    .                      .
}                      }
```

Each expression is only true when number has value 0

What output? and Why?

```
int  age;

age = 20;

if  (age = 16)
{
  cout << "Did you get driver's license?";
}
```


What output? and Why?

```
int  age;

age =  30;

if  (age <  18)

    cout << "Do you drive?";
    cout << "Too young to vote";
```


What output? and Why?

```
int  code;

code = 0;

if  (!code)
    cout << "Yesterday";
else
    cout << "Tomorrow";
```


What output? and Why?

```
int  number;

number = 2;

if  (number = 0)

    cout << "Zero value";
else
    cout << "Non-zero value";
```

Note

Both the if clause and the else clause of an if-else statement can contain any kind of statement, including another selection statement.

Nested Selection

Multi-alternative is also called multi-way branching, and can be accomplished by using NESTED `if` or `if-else` statements.

Nested if-else Statement

```
if (Boolean expression)
    Statement1;
else if (Boolean expression)
         Statement2;
     else
         Statement3;
```


Nested if Statements

- Each Expression is evaluated in sequence, until some Expression is found that is true.
- Only the specific Statement following that particular true Expression is executed.
- If no Expression is true, the Statement following the final else is executed.
- Actually, the final else and final Statement are optional. If omitted, and no Expression is true, then no Statement is executed.

Nested Selections

```
if (creditsEarned >= 90)
   cout << "SENIOR STATUS ";
else if (creditsEarned >= 60)
        cout << "JUNIOR STATUS ";
     else if (creditsEarned >= 30)
             cout << "SOPHOMORE STATUS ";
          else
             cout << "FRESHMAN STATUS ";
```


Example

```
if (Average >= 90)
   cout<<"Your grade is an A";
else if (Average >= 80)
        cout<<"Your grade is a B";
     else if (Average >= 70)
             cout<<"Your grade is a C";
          else if (Average >= 60)
                  cout<<"Your grade is a D";
               else
                  cout<<"Your grade is an F";
```


Writing Nested if Statements

- Display one word to describe the int value of number as "Positive", "Negative", or "Zero"

```
if (number >  0)
     cout << "Positive";
else if (number < 0)
        cout << "Negative";
     else
        cout << "Zero";
```


Writing Nested if Statements

Your city classifies a pollution index

- less than 35 as "Pleasant",
- 35 through 60 as "Unpleasant",
- and above 60 as "Health Hazard."
- Display the correct description of the
- pollution index value.

```
if (index < 35)
      cout << "Pleasant";
else if (index <= 60)
        cout << "Unpleasant";
     else
        cout << "Health Hazard";
```

Example

Every Monday thru Friday you go to class

When it is raining you take an umbrella

But on the weekend, what you do depends on the weather

If it is raining you read in bed

Otherwise, you have fun outdoors

Code

```
// Program tells how to spend your day
#include < iostream >
using namespace std;
void main (void)
{
    int      day;
    char   raining;
    cout << "Enter day (use 1 for Sunday)";
    cin   >>  day;
    cout << "Is it raining? (Y/N)";
    cin   >>  raining;
    if  ((day == 1) || (day == 7))
    { // Sat or Sun
        if  (raining == 'Y')
              cout << "Read in bed";
        else
              cout << "Have fun outdoors";
    }
    else
    {
        cout << "Go to class ";
        if  (raining == 'Y')
            cout << "Take an umbrella";
    }
}
```

Caution

In the absence of braces,

an `else` is always paired with the closest preceding `if` that doesn't already have an `else` paired with it

Example

```
float average;

average = 100.0;

if  (average >= 60.0)
{
     if (average < 70.0)
        cout << "Marginal
  PASS";
 }
else
     cout << "FAIL";
```

FAIL is printed; WHY?

The compiler ignores indentation and pairs the else with the second if

Each I/O stream has a state (condition)

- An *input stream* enters fail state when you
  - try to read invalid input data
  - try to open a file which does not exist
  - try to read beyond the end of the file
- An *output stream* enters fail state when you
  - try to create a file with an invalid name
  - try to create a file on a write-protected disk
  - try to create a file on a full disk

How can you tell the state?

- The *stream identifier* can be used as if it were a Boolean variable. It has value `false` (meaning the last I/O operation on that stream failed) when the stream is in fail state.
- When you use a file stream, you should check on its state.

Checking on the I/O State

```
fstream  myOutfile;

myOutfile.open ("A:\\myOut.dat",ios::out);

if (! myOutfile)
{
   cout << "File opening  error.  "
       << "Program terminated." << endl;
   return 1;
}
// otherwise send output to myOutfile
```


Testing Selection Control Structures

- to test a program with branches, use enough data sets so that every branch is executed at least once
- this is called minimum complete coverage

Testing Often Combines Two Approaches

WHITE BOX TESTING	BLACK BOX TESTING
Code Coverage	**Data Coverage**
Allows us to see the program code while designing the tests, so that data values at the boundaries, and possibly middle values, can be tested.	**Tries to test as many allowable data values as possible without regard to program code.**

How to Test a Program

- design and implement a test plan
- a test plan is a document that specifies the test cases to try, the reason for each, and the expected output
- implement the test plan by verifying that the program outputs the predicted results

PHASE	RESULT	TESTING TECHNIQUE
Problem solving	Algorithm	Algorithm walk-through
Implementation	Coded program	Code walk-through, Trace
Compilation	Object program	Compiler messages
Execution	Output	Implement test plan

Body Mass Index Problem

Problem Implement a measure called the Body Mass Index (BMI), which computes a ratio of your weight and height, which has become a popular tool to determine an appropriate weight. The formula for non-metric values is

$$BMI = weight * 703 / height^2$$

What is the BMI?

BMI correlates with body fat, which can be used to determine if a weight is unhealthy for a certain height. Do a search of the Internet for "body mass index" and you will find more than a million hits. In these references, the formula remains the same but the interpretation varies somewhat, depending on age and sex. Here is a the most commonly used generic interpretation.

BMI	***Interpretation***
< 20	**Underweight**
20-25	**Normal**
26-30	**Overweight**
over 30	**Obese**

Algorithm

Get Data Level 1

- Prompt for weight
- Read weight
- Prompt for height
- Read height

Test Data

```
IF weight < 0 OR  height < 0
   Set dataAreOK to false
ELSE
   Set dataAreOK to true
```

Calculate BMI

Set bodyMassIndex to weight * 703 / height ^{2}

Algorithm Continued

Print

```
Print "Your BMI is ", bodyMassIndex,   '.'
Print "Interpretation and instructions."
IF bodyMassIndex <20
  Print "Underweight: Have a milk shake."
ELSE IF bodyMassIndex < 26
  Print "Normal: Have a glass of milk."
ELSE IF bodyMassIndex < 30
  Print  "Overweight:  Have  a  glass  of  iced
tea."
ELSE
  Print "Obese: See your doctor."
```

C++ Program

```
//*************************************************
// BMI Program
// This program calculates the body mass index (BMI)
// given a weight in pounds and a height in inches and
// prints a health message based on the BMI.
//*************************************************
#include <iostream>
using namespace std;
int main()
{
    const int BMI_CONSTANT = 703; // Non-metric constant
    float weight;                 // Weight in pounds
    float height;                 // Height in inches
    float bodyMassIndex;          // Appropriate BMI
    bool dataAreOK;               // True if data OK
```

```
    // Calculate body mass index
    bodyMassIndex = weight * BMI_CONSTANT
            / (height * height);
    // Print message indicating status
    cout << "Your BMI is "
         << bodyMassIndex << ". " << endl;
    cout << "Interpretation and instructions. "
         << endl;
    if (bodyMassIndex < 20)
        cout << "Underweight: ...." << endl;
    else if (bodyMassIndex <= 25)
        cout << "Normal: ...."  << endl;
    else if (bodyMassIndex <=  30)
        cout << "Overweight:...."  << endl;
    else
        cout << "Obese: ...." << endl;
    return 0;
}
```

Testing the BMI Program

- There is no testing in this program, but there should be!!
- Should you use white box or black box testing?
- What test should be included?
- Where should they be inserted?