J. P. Cohoon and J. W. Davidson

Control Constructs

Mechanisms for deciding when and how often an action should be taken

Boolean Algebra

- Logical expressions have the one of two values - true or false
  - A rectangle has three sides.
  - The instructor has a pleasant smile
- The branch of mathematics that deals with this type of logic is called Boolean algebra
  - Developed by the British mathematician George Boole in the 19th century
- Three key logical operators
  - *And*
  - *Or*
  - *Not*

Boolean Algebra

- Truth tables
  - Lists all combinations of operand values and the result of the operation for each combination
- Example

P	Q	P *and* Q
False	False	False
False	True	False
True	False	False
True	True	True

Boolean Algebra

- Truth table for or

P	Q	P *or* Q
False	False	False
False	True	True
True	False	True
True	True	True

Boolean Algebra

- Truth table for not

P	*Not* P
False	True
True	False

Boolean Algebra

- Can create complex logical expressions by combining simple logical expressions
- Example
  - not (P and Q)
- A truth table can be used to determine when a logical expression is true

P	Q	P and Q	not (P and Q)
False	False	False	True
False	True	False	True
True	False	False	True
True	True	True	False

A Boolean Type

- C++ contains a type named `bool`
- Type `bool` has two symbolic constants
  - `true`
  - `false`
- Boolean operators
  - The *and* operator is `&&`
  - The *or* operator is `||`
  - The *not* operator is `!`
- Warning
  - `&` and `|` are also operators

A Boolean Type

- Example logical expressions

```
bool P = true;
bool Q = false;
bool R = true;
bool S = P && Q;
bool T = !Q || R;
bool U = !(R && !Q);
```

Relational Operators

- Equality operators
  - `==`
  - `!=`
- Examples
  - `int i = 32;`
  - `int k = 45;`
  - `bool q = i == k;`
  - `bool r = i != k;`

Relational Operators

- Ordering operators
  - `<`
  - `>`
  - `>=`
  - `<=`
- Examples
  - `int i = 5;`
  - `int k = 12;`
  - `bool p = i < 10;`
  - `bool q = k > i;`
  - `bool r = i >= k;`
  - `bool s = k <= 12;`

Operator Precedence Revisited

- Precedence of operators (from highest to lowest)
  - Parentheses
  - Unary operators
  - Multiplicative operators
  - Additive operators
  - Relational ordering
  - Relational equality
  - Logical and
  - Logical or
  - Assignment

Operator Precedence Revisited

- Examples

```
5 != 6 || 7 <= 3

(5 !=6) || (7 <= 3)

5 * 15 + 4 == 13 && 12 < 19 || !false == 5 < 24
```

Conditional Constructs

- Provide
  - Ability to control whether a statement list is executed
- Two constructs
  - If statement
    - If
    - If-else
    - If-else-if
  - Switch statement

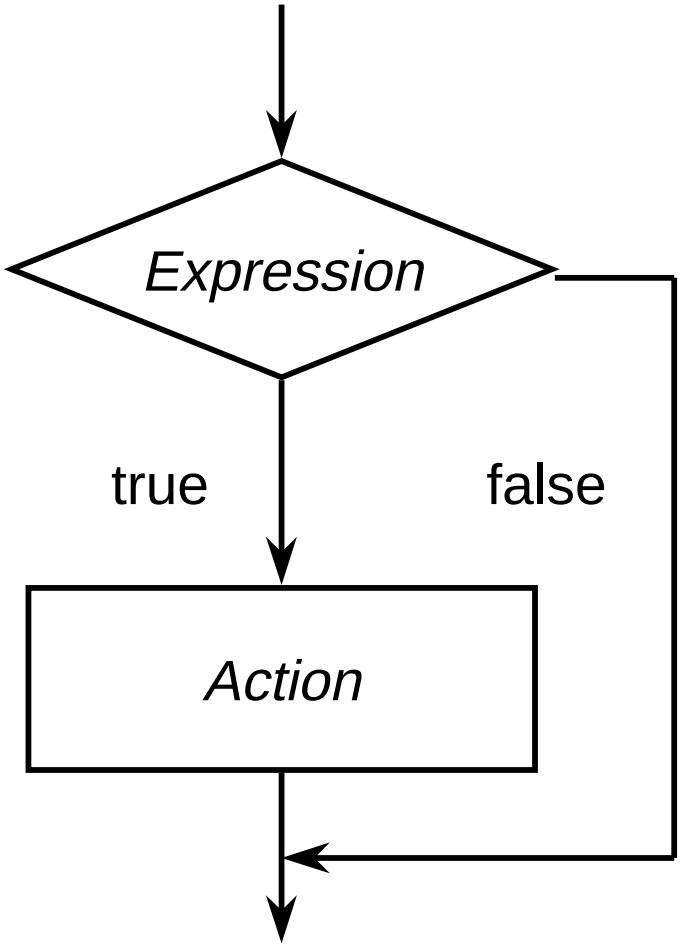
The Basic If Statement

- Syntax

```
if (Expression)
    Action
```

- If the *Expression* is true then execute *Action*
- *Action* is either a single statement or a group of statements within braces
- Example

```
if (Value < 0) {
    Value = -Value;
}
```



Sorting Two Numbers

```
cout << "Enter two integers: ";
int Value1;
int Value2;
cin >> Value1 >> Value2;
if (Value1 > Value2) {
   int RememberValue1 = Value1;
   Value1 = Value2;
   Value2 = RememberValue1;
}
cout << "The input in sorted order: "
 << Value1 << " " << Value2 << endl;
```

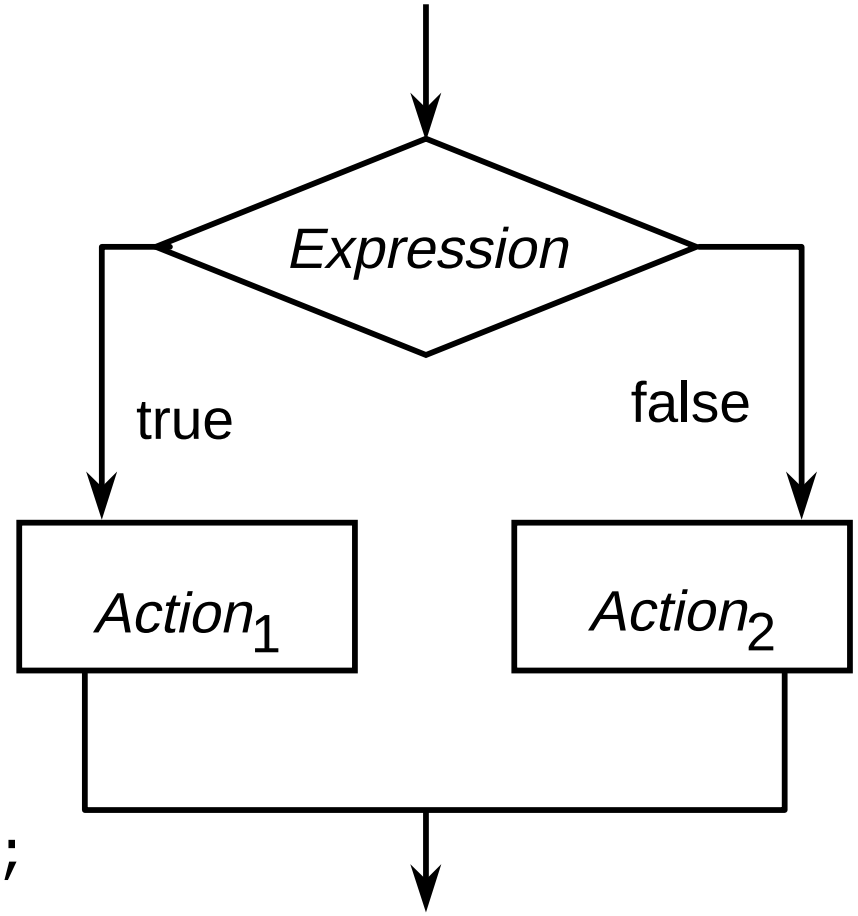
The If-Else Statement

- Syntax

```
if (Expression)
    Action1
else
    Action2
```

- If *Expression* is true then execute $Action_1$ otherwise execute $Action_2$

```
if (v == 0) {
   cout << "v is 0";
}
else {
   cout << "v is not 0";
}
```



Finding the Larger of Two Values

```
cout << "Enter two integers: ";
int Value1;
int Value2;
cin >> Value1 >> Value2;
int Larger;
if (Value1 < Value2) {
   Larger = Value1;
}
else {
   Larger = Value2;
}
cout << "Larger of inputs is: " Larger << endl;
```

Selection

- It is often the case that depending upon the value of an expression we want to perform a particular action
- Two major ways of accomplishing of this choice
  - If-else-If statement
    - If-else statements “glued” together
  - Switch statement
    - An advanced construct

The If-Else-If Statement

- Example

```
if ((ch == 'a') || (ch == 'A"))
    cout << ch << " is a vowel" << endl;
else if ((ch == 'e') || (ch == 'E"))
    cout << " ch << " is a vowel" << endl;
else if ((ch == 'i') || (ch == 'I"))
    cout << ch << " is a vowel" << endl;
else if ((ch == 'o') || (ch == 'O"))
    cout << ch << " is a vowel" << endl;
else if ((ch == 'u') || (ch == 'U"))
    cout << ch << " is a vowel" << endl;
else
    cout << ch << " is not a vowel" << endl;
```

Switch Statement

```
switch (ch) {
   case 'a': case 'A":
   case 'e': case 'E":
   case 'i': case 'I":
   case 'o': case 'O":
   case 'u': case 'U":
       cout << ch << " is a vowel" << endl;
       break;
   default:
       cout << ch << " is not a vowel" << endl;
}
```

```
cout << "Enter simple expression: ";
int Left;
int Right;
char Operator;
cin >> Left >> Operator >> Right;
cout << Left << " " << Operator << " " << Right
 << " = ";
switch (Operator) {
  case '+' : cout << Left + Right << endl; break;
  case '-' : cout << Left - Right << endl; break;
  case '*' : cout << Left * Right << endl; break;
  case '/' : cout << Left / Right << endl; break;
  default: cout << "Illegal operation" << endl;
}
```

Iterative Constructs

- Provide
  - Ability to control how many times a statement list is executed
- Three constructs
  - while statement
  - for statement
  - do-while statement

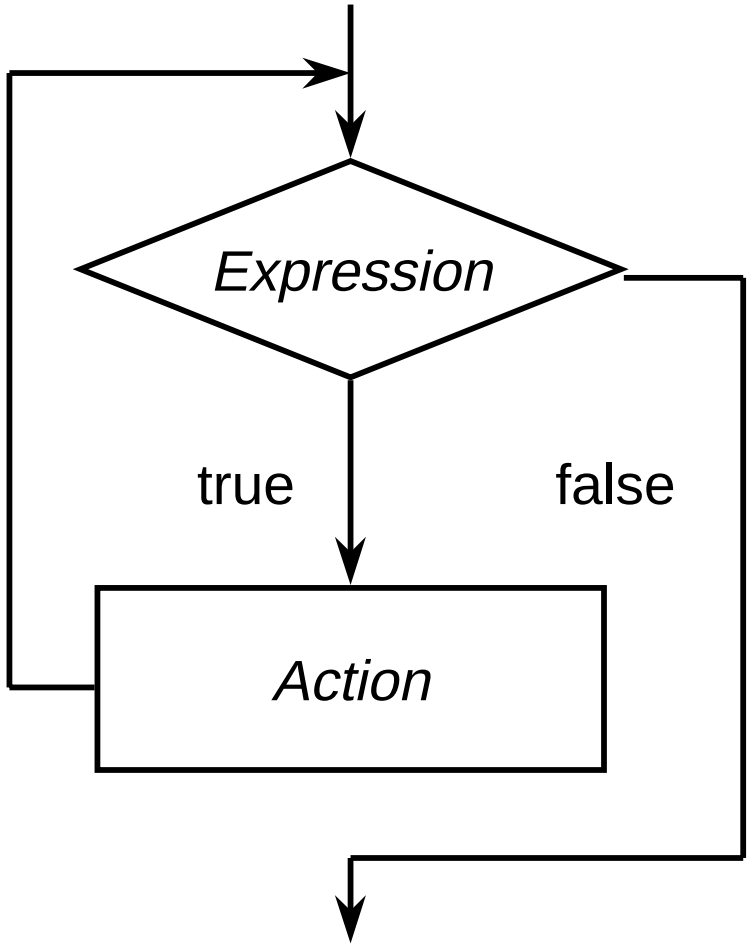
The While Statement

- Syntax

  `while (`*Expression*`)`

  Action

- Semantics
  - If *Expression* is true then execute Action
  - Repeat this process until *Expression* evaluates to false
- *Action* is either a single statement or a group of statements within braces



Power of Two Table

```
const int TableSize = 20;

int i = 0;
long Value = 1;

cout << "i" << "\t\t" << "2 ** i" << endl;

while (i <= TableSize) {
    cout << i << "\t\t" << Value << endl;
    Value *= 2;
    ++i;
}
```

Character Counting

```
int NumberOfNonBlanks = 0;
int NumberOfUpperCase = 0;
char c;
while (cin >> c) {

    ++NumberOfNonBlanks;

    if ((c >= 'A') && (c <= 'Z')) {
       ++NumberOfUpperCase;
    }
}
```

Counting Characters

```
char c;
int NumberOfCharacters = 0;
int NumberOfLines = 0;
while (cin.get(c)) {
    ++NumberOfCharacters;
    if (c == '\n')
       ++NumberOfLines
}
cout << "Characters: " << NumberOfCharacters
 << endl;
cout << "Lines: " << NumberOfLines << endl;
```

```
int main() {
      cout << "Provide a list of numbers" << endl;
      int ListSize = 0;
      float ValueSum = 0;
      int Value;
      while (cin >> Value) {
         ValueSum += Value;
         ++ListSize;
      }
      if (ListSize > 0) {
         float Average = ValueSum / ListSize;
         cout << "Average: " << Average << endl;
      }
      else {
         cout << "No list to average" << endl;
      }
      return 0;
  }
```

The value of the input operation corresponds to true only if a successful extraction was made

The For Statement

- Syntax

  `for` (*ForInit* ; *ForExpression*; *PostExpression*)

  Action

- Semantics
  - Execute *ForInit* statement
  - While *ForExpression* is true
    - Execute *Action*
    - Execute *PostExpression*
- Example

```
for (int i = 0; i < 20; ++i) {
   cout << "i is " << i << endl;
}
```

Iteration Using the For Statement

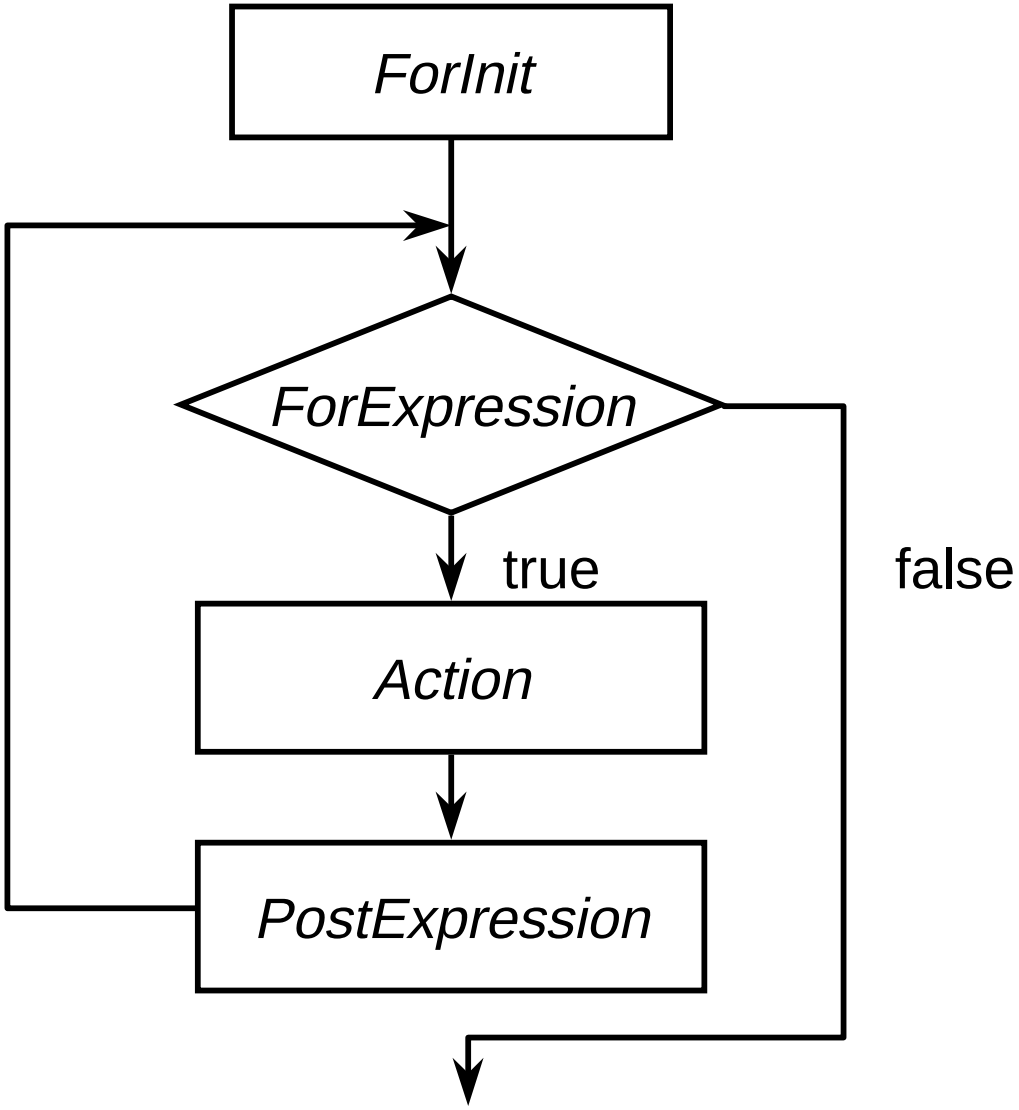


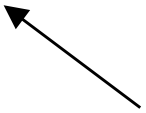
Table Revisiting

```
const int TableSize = 20;

long Value = 1;

cout << "i" << "\t\t" << "2**i" << endl;

for (int i = 0; i <= TableSize; ++i) {
    cout << i << "\t\t" << Value << endl;
    Value *= 2;
}
```

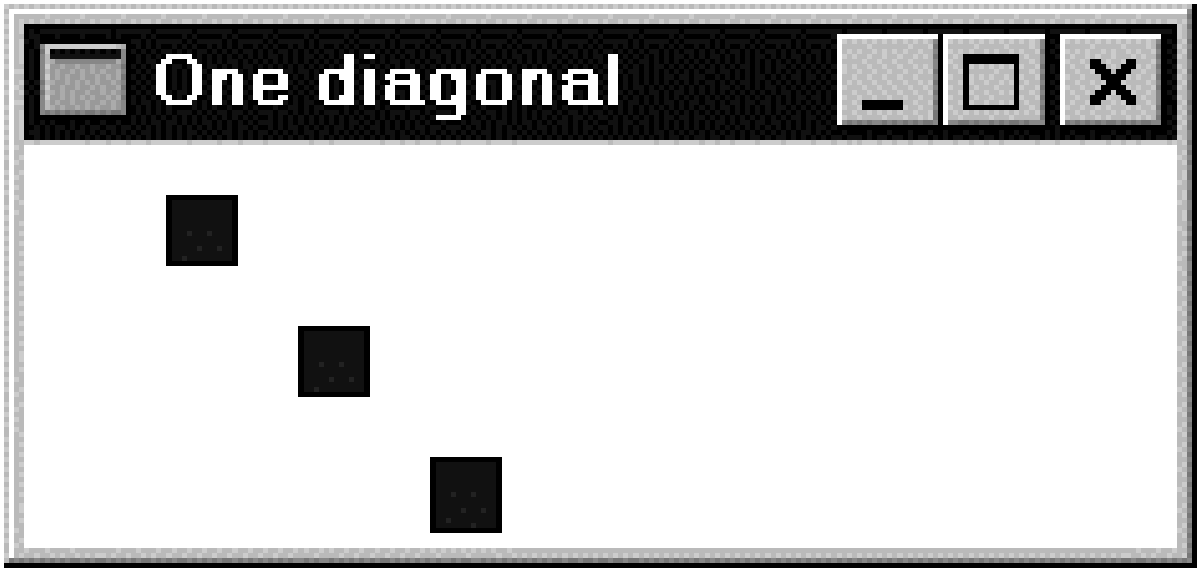


The scope of i is limited to the loop!

Displaying A Diagonal

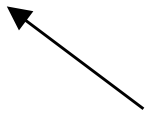
```
SimpleWindow W("One diagonal", 5.5, 2.25);
W.Open();
for (int j = 1;  j <= 3; ++j) {
  float x = j * 0.75 + 0.25;
  float y = j * 0.75 - 0.25;
  float Side = 0.4;
  RectangleShape S(W, x, y, Blue, Side, Side);
  S.Draw();
}
```

Sample Display



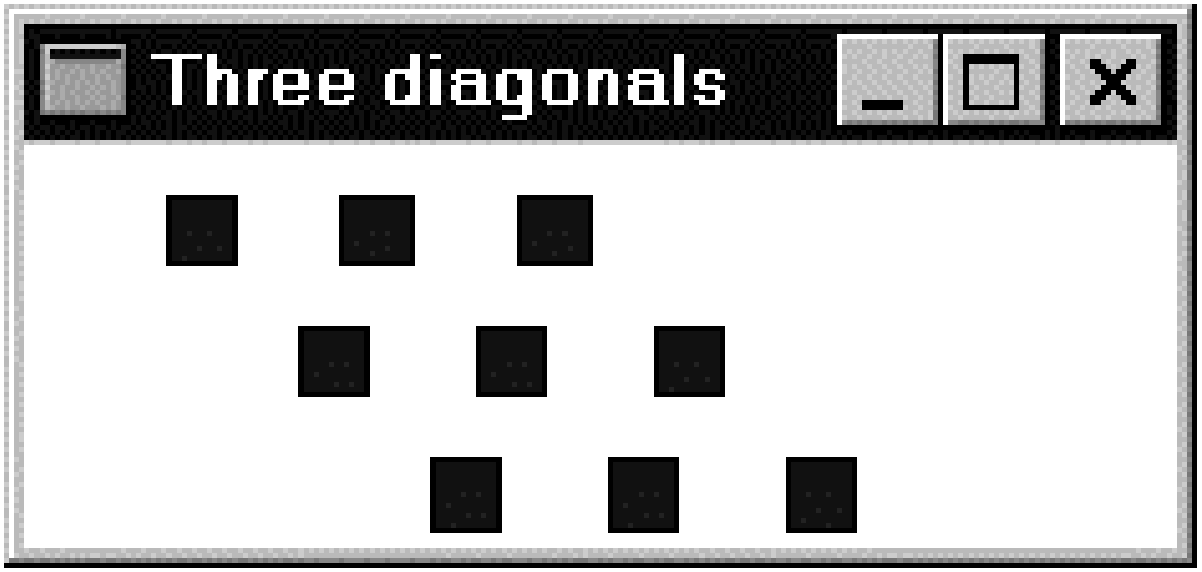
Displaying Three Diagonals

```
SimpleWindow W("Three diagonals", 6.5, 2.25);
W.Open();
for (int i = 1; i <= 3; ++i) {
   for (int j = 1;  j <= 3; ++j) {
     float x = i - 1 + j * 0.75 + 0.25;
     float y = j * 0.75 - 0.25;
     float Side = 0.4;
     RectangleShape S(W, x, y, Blue, Side, Side);
     S.Draw();
   }
}
```



The scope of i includes the inner loop.
The scope of j is just the inner loop.

Sample Display



```
int Counter1 = 0;
int Counter2 = 0;
int Counter3 = 0;
int Counter4 = 0;
int Counter5 = 0;
++Counter1;
for (int i = 1; i <= 10; ++i) {
  ++Counter2;
  for (int j = 1; j <= 20; ++j) {
      ++Counter3;
  }
  ++Counter4;
}
++Counter5;
cout << Counter1 << " " << Counter2 << " " <<
 Counter3 << " " Counter4 << " " Counter5 << endl;
```

For Into While

- Observation
  - The for statement is equivalent to

```
{
ForInit;
while (ForExpression) {
  Action;
  PostExpression;
  }
}
```

Iteration

- Key Points
  - Make sure there is a statement that will eventually nullify the iteration criterion (i.e., the loop must stop)
  - Make sure that initialization of any loop counters or iterators is properly performed
  - Have a clear purpose for the loop
    - Document the purpose of the loop and how the body of the loop advances the purpose of the loop

Riddle

- Four hobos traveling across the country in need of money
- Farmer offers 200 hours of work that could be done over the next couple of weeks
- The laziest hobo convinces the other three hobos to draw straws
- Each straw would be marked with an amount
  - The amount would represent both the number of days and the numbers of hours per day that the hobo would work
  - Example
    - If the straw was marked three then the hobo who drew it would work for three hours per day for three days
- What are the best markings of the straws for a clever, lazy hobo?

Observations

- Need to find sets of whole numbers a, b, c, and d such that
  - $a^2 + b^2 + c^2 + d^2 = 200$
- Maximal legal number is 14 as 15^2 equals 225 which is greater than 200
- Minimal legal number is 1
- No advantage to listing the combinations more than once
  - Implication
    - Generate the solutions systematically
  - We will make sure that a <= b <= c <= d

Method

- Generate all possibilities for a where for each a possibility
  - Generate all possibilities of b where for each b possibility
    - Generate all possibilities for c where for each c possibility
      - Generate all possibilities for d where for each d possibility
        - Determine whether the current combination is a solution

Nested For Loop Solution

```
for (int a = 1; a <= 14; ++a) {
   for (int b = a; b <= 14; ++b) {
      for (int c = b; c <= 14; ++c) {
         for (int d = c; (d <= 14); ++d) {
            if (a*a + b*b + c*c + d*d == 200) {
               cout << a << " " << b << " " << c
                << " " << d << endl;
            }
         }
      }
   }
}
```

Simple Visualization

- What statements can we make about the following data set?

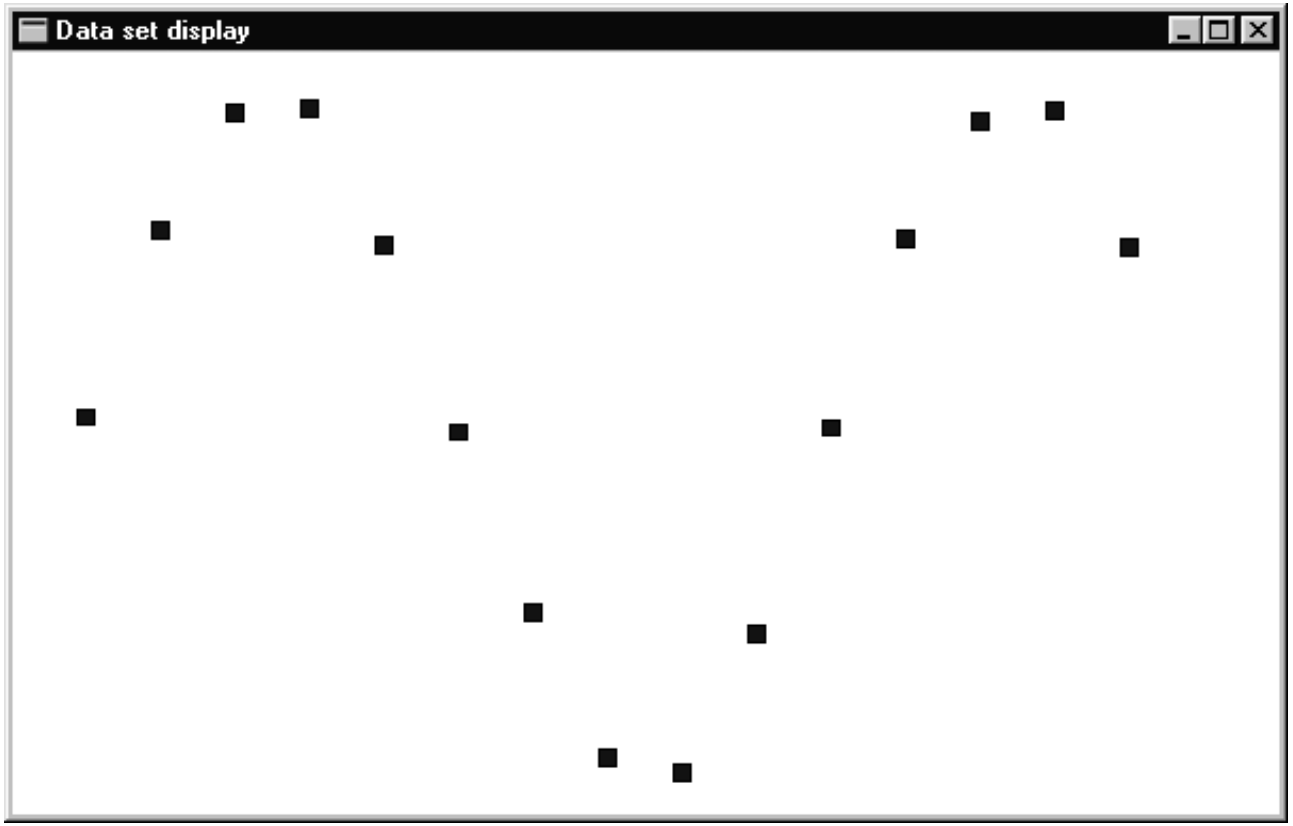
  4.90 2.41 0.82 0.77 2.60 5.10 7.52 9.45 9.65
  7.81 5.04 2.51 0.95 0.80 2.62

- Statistical analysis analysis indicates that observations come from interval 0 … 10 with an average value of 4.97 and a standard deviation of 2.95
- Another approach is to detect whether the sequence of observations represents a patter
  - Are the numbers arranged for example in Fibonacci order?
- If no patterns are recognized, try data visualization
  - Plot the data set values in a two-dimensional manner
    - y-axis correspond to data set values
    - x-axis correspond to positions in the data set sequence

```
#include <iostream>                          // Program 4.12
#include <string>
#include "rect.h"
using namespace std;
int ApiMain() {
   const float Unit = 0.25;
   cout << "Enter size of data set: ";
   int n;
   cin >> n;
   SimpleWindow W("Data set display", n+2, 10);
   W.Open();
   for (float x = 1; x <= n; ++x) {
       cout << "Enter data value (n): ";
       float y;
       cin >> y;
       RectangleShape Point(W, x, y, Blue, Unit, Unit);
       Point.Draw();
   }
    return 0;
}
```

Sample Run

- Data values do have structure

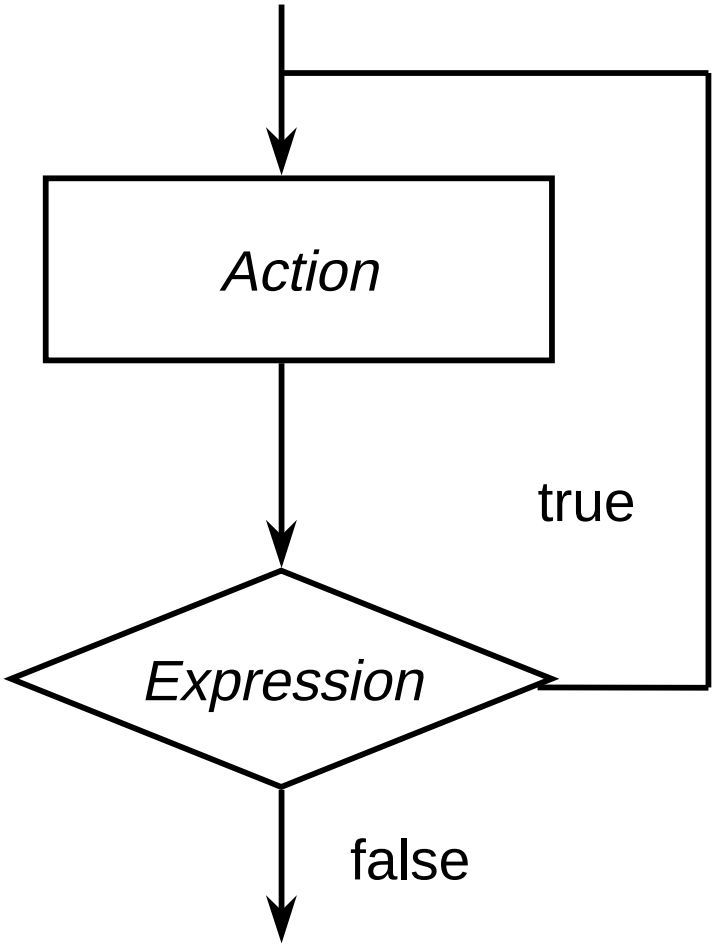


The Do-While Statement

- Syntax

  `do` *Action*

  `while (`*Expression*`)`
- Semantics
  - Execute *Action*
  - if *Expression* is true then execute *Action* again
  - Repeat this process until *Expression* evaluates to false
- *Action* is either a single statement or a group of statements within braces



Waiting for a Proper Reply

```
char Reply;
do {
   cout << "Decision (y, n): ";
   if (cin >> Reply)
      Reply = tolower(Reply);
   else
      Reply = 'n';
} while ((Reply != 'y') && (Reply != 'n'));
```