Functions, Arrays & Structs

Unit 1
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Function Definitions

- Function definition pattern:
  
  ```
  datatype identifier (parameter1, parameter2, ...) {
  statements . . .
  }
  ```

  Where a parameter is:
  
  ```
  datatype identifier
  ```

- `datatype`: the type of data returned by the function.
- `identifier`: the name by which it is possible to call the function.
- `parameters`: Like a regular variable declaration, act within the function as a regular local variable. Allow passing arguments to the function when it is called.
- `statements`: the function's body, executed when called.

Function Call, Return Statement

- **Function call** expression
  
  ```
  identifier ( expression1, . . . )
  ```

  - Causes control flow to enter body of function named `identifier`.
  - `parameter1` is initialized to the value of `expression1`, and so on for each parameter.
  - `expression1` is called an argument.

- **Return statement**: return expression;
  
  - inside a function, causes function to stop, return control to caller.
  - The value of the return expression becomes the value of the function call.

Example: Function

```
// function example
#include <iostream>
using namespace std;
int addition (int a, int b) {
  int result;
  result=a+b;
  return result;
}
int main () {
  int z;
  z = addition (5,3);
  cout << "The result is " << z <<endl;
}
```

- What are the parameters? arguments?
- What is the value of: `addition (5,3)`?
- What is the output?
Void function

- A function that returns no value:

```cpp
void printAddition (int a, int b) {
    int result;
    result = a + b;
    cout << "the answer is: " << result << endl;
}
```
- use void as the return type.
- the function call is now a statement (it does not have a value)

```cpp
int main () {
    printAddition (5, 3);
}
```

Prototypes

- In a program, function definitions must occur before any calls to that function
- To override this requirement, place a prototype of the function before the call.
- The pattern for a prototype:

```
datatype identifier (type1, type2, ...);
```
- the function header without the body (parameter names are optional).

Arguments passed by value

- **Pass by value**: when an argument is passed to a function, its value is *copied* into the parameter.
- It is implemented using variable initialization (behind the scenes):
  ```cpp
  int param = argument;
  ```
- Changes to the parameter in the function body do **not** affect the value of the argument in the call
- The parameter and the argument are stored in separate variables; separate locations in memory.

Example: Pass by Value

```cpp
#include <iostream>
using namespace std;

void changeMe(int);

int main() {
    int number = 12;
    cout << "number is " << number << endl;
    changeMe(number);
    cout << "Back in main, number is " << number << endl;
    return 0;
}

void changeMe(int myValue) {
    myValue = 200;
    cout << "myValue is " << myValue << endl;
}
```

Output:

```
number is 12
myValue is 200
Back in main, number is 12
```

changeMe failed to change the argument!
Parameter passing by Reference

- **Pass by reference**: when an argument is passed to a function, the function has direct access to the original argument (no copying).
- Pass by reference in C++ is implemented using a reference parameter, which has an ampersand (&) in front of it:
  ```cpp
  A reference parameter acts as an alias to its argument, it is NOT a separate storage location.
  Changes to the parameter in the function DO affect the value of the argument
  ```

Example: Pass by Reference

```cpp
#include <iostream>
using namespace std;

void changeMe(int &);

int main() {
    int number = 12;
    cout << "number is " << number << endl;
    changeMe(number);
    cout << "Back in main, number is " << number << endl;
    return 0;
}

void changeMe(int &myValue) {
    myValue = 200;
    cout << "myValue is " << myValue << endl;
}
```

Output:
```
number is 12
myValue is 200
Back in main, number is 200
```

Scope of variables

- For a given variable definition, in which part of the program can it be accessed?
  - **Global variable** (defined outside of all functions): can be accessed anywhere, after its definition.
  - **Local variable** (defined inside of a function): can be accessed inside the block in which it is defined, after its definition.
  - **Parameter**: can be accessed anywhere inside of its function body.
- Variables are destroyed at the end of their scope.

More scope rules

- Variables in the same exact scope cannot have the same name
  - Parameters and local function variables cannot have the same name
  - Variable defined in inner block can hide a variable with the same name in an outer block.
- Variables defined in one function cannot be seen from another.

```cpp
int x = 10;
if (x < 100) {
    int x = 30;
    cout << x << endl;
}
cout << x << endl;
```

Output:
```
30
10
```
Overloaded Functions

- Overloaded functions have the same name but different parameter lists.
- The parameter lists of each overloaded function must have different types and/or number of parameters.
- Compiler will determine which version of the function to call by matching arguments to parameter lists.

Example: Overloaded functions

```cpp
double calcWeeklyPay (int hours, double payRate) {
    return hours * payRate;
}
double calcWeeklyPay (double annSalary) {
    return annSalary / 52;
}

int main () {
    int h;
    double r;
    cout << "Enter hours worked and pay rate: ";
    cin >> h >> r;
    cout << "Pay is: " << calcWeeklyPay(h, r) << endl;
    cout << "Enter annual salary: ";
    cin >> r;
    cout << "Pay is: " << calcWeeklyPay(r) << endl;
    return 0;
}
```

Output:
Enter hours worked and pay rate: 37 19.5
Pay is: 721.5
Enter annual salary: 75000
Pay is: 1442.31

Default Arguments

- A **default argument** for a parameter is a value assigned to the parameter when an argument is not provided for it in the function call.
- The default argument patterns:
  - in the prototype:
    ```cpp
datatype identifier (type1 = c1, type2 = c2, ...);
```
  - OR in the function header:
    ```cpp
datatype identifier (type1 p1 = c1, type2 p2 = c2, ...) {
    ...
}
```
- c1, c2 are constants (named or literals)

Example: Default Arguments

```cpp
void showArea (double length = 20.0, double width = 10.0) {
    double area = length * width;
    cout << "The area is " << area << endl;
}
```

- This function can be called as follows:
  - `showArea();` ==> uses 20.0 and 10.0
    The area is 200
  - `showArea(5.5, 2.0);` ==> uses 5.5 and 2.0
    The area is 11
  - `showArea(12.0);` ==> uses 12.0 and 10.0
    The area is 120
Arrays

- An array is:
  - A series of elements of the same type
  - placed in contiguous memory locations
  - that can be individually referenced by using an index along with the array name.

- To declare an array:
  
  ```
  datatype identifier [size];
  ```

  - datatype is the type of the elements
  - identifier is the name of the array
  - size is the number of elements (constant)

Array initialization

- To specify contents of the array in the definition:
  
  ```
  float scores[3] = {86.5, 92.1, 77.5};
  ```

  - creates an array of size 3 containing the specified values.

  ```
  float scores[10] = {86.5, 92.1, 77.5};
  ```

  - creates an array containing the specified values followed by 7 zeros (partial initialization).

  ```
  float scores[] = {86.5, 92.1, 77.5};
  ```

  - creates an array of size 3 containing the specified values (size is determined from list).

Array access

- to access the value of any of the elements of the array individually, as if it was a normal variable:
  
  ```
  scores[2] = 89.5;
  ```

  - scores[2] is a variable of type float

- rules about subscripts (aka indexes):
  - they always start at 0, last subscript is size-1
  - the subscript must have type int
  - they can be any expression

- watchout: brackets used both to declare the array and to access elements.

Arrays: operations

- Valid operations over entire arrays:
  - function call: myFunc(scores, x);

- **Invalid** operations over entire arrays:
  - assignment: array1 = array2;
  - comparison: array1 == array2
  - output: cout << array1;
  - input: cin >> array2;

  - Must do these element by element, probably using a for loop
Processing arrays

• **Assignment**: copy one array to another

```c
const int SIZE = 4;
int oldValues[SIZE] = {10, 100, 200, 300};
int newValues[SIZE];
for (int count = 0; count < SIZE; count++)
    newValues[count] = oldValues[count];
```

• **Output**: displaying the contents of an array

```c
const int SIZE = 5;
int numbers[SIZE] = {10, 20, 30, 40, 50};
for (int count = 0; count < SIZE; count++)
    cout << numbers[count] << endl;
```

Example: Processing arrays

Computing the average of an array of scores:

```c
const int NUM_SCORES = 8;
int scores[NUM_SCORES];
cout << "Enter the " << NUM_SCORES << " programming assignment scores: " << endl;
for (int i=0; i < NUM_SCORES; i++)
    cin >> scores[i];
int total = 0;  //initialize accumulator
for (int i=0; i < NUM_SCORES; i++)
    total = total + scores[i];
double average = static_cast<double>(total) / NUM_SCORES;
```

Finding highest and lowest values in arrays

• **Maximum**: Need to track the highest value seen so far. Start with highest = first element.

```c
const int SIZE = 5;
int array[SIZE] = {10, 100, 200, 30};
int highest = array[0];
for (int count = 1; count < SIZE; count++)
    if (array[count] > highest)
        highest = array[count];
cout << "The maximum value is " << highest << endl;
```

Arrays as parameters

• In the **function definition**, the parameter type is a variable name with an empty set of brackets: 

  - Do **NOT** give a size for the array inside []

    ```c
    void showArray(int values[], int size)
    ```

• In the **prototype**, empty brackets go after the element datatype.

    ```c
    void showArray(int[], int)
    ```

• In the **function call**, use the variable name for the array.

    ```c
    showArray(numbers, 5)
    ```

• An array is **always passed by reference**.
Two-Dimensional Arrays

- Like a table in a spreadsheet: rows and columns
- Declaration requires two size declarators:
  ```
  int table[5][3]; // 5 rows, 3 columns
  ```
- Rows are always first
- 2D arrays can be initialized:
  ```
  int table[2][3] =
  { {1, 2, 3},
    {4, 5, 6} };
  ```

Two-Dimensional Array processing

- Access an element of the array using two indices:
  ```
  int table[2][3] =
  { {1, 2, 3},
    {4, 5, 6} }; cout << table[0][2];
  ```
  Output: 3
- Two dimensional arrays can be passed to functions.
- The number of **columns** is required in the parameter declaration:
  ```
  void showTable (int array[][3], int rows) {
    ...
  }
  ```

Two-Dimensional Array functions

- 2D array processing usually requires nested for loops:
  ```
  void showTable (int array[][3], int rows) {
    for (int x=0; x<rows; x++) {
      for (int y=0; y<3; y++)
        cout << setw(4) << array[x][y] << " ";
      cout << endl;
    }
  }
  ```
- How showTable is called:
  ```
  int table[2][3] =
  { {1, 2, 3},
    {4, 5, 6} };
  showTable(table,2);
  ```

Structures

- A structure stores a collection of objects of various types
- Each element in the structure is a member, and is accessed using the dot member operator.
  ```
  struct Student {
    int idNumber;
    string name;
    int age;
    string major;
  };
  ```
  Defines a new data type
  ```
  struct Student1, student2;  // Defines new variables
  student1.name = "John Smith";
  student1.name = {123456,"Ann Page",22,"Math"};
  ```
Structures: operations

- Valid operations over entire structs:
  - assignment: `student1 = student2;`
  - function call: `myFunc(gradStudent,x);`

- **Invalid** operations over structs:
  - comparison: `student1 == student2`
  - output: `cout << student1;`
  - input: `cin >> student2;`
  - Must do these member by member

Arrays of Structures

- You can store values of structure types in arrays.
  ```
  Student roster[40];  //holds 40 Student structs
  ```

- Each student is accessible via the subscript notation.
  ```
  roster[0] = student1;
  ```

- Members of structure accessible via dot notation
  ```
  cout << roster[0].name << endl;
  ```

Arrays of Structures: initialization

- To initialize an array of structs:
  ```
  struct Student {
    int idNumber;
    string name;
    int age;
    string major;
  };
  int main()
  {
    Student roster[] = {
      {111222,"Jack Spade",18,"Physics"}
    };
  }
  ```

Arrays of Structures

- Arrays of structures processed in loops:
  ```
  Student roster[40];
  //input
  for (int i=0; i<40; i++) {
    cout << "Enter the name, age, idNumber and "
    << "major of the next student: \n";
    cin >> roster[i].name >> roster[i].age
    >> roster[i].idNumber >> roster[i].major;
  }

  //output all the id numbers and names
  for (int i=0; i<40; i++) {
    cout << roster[i].idNumber << endl;
    cout << roster[i].name << endl;
  }
  ```