Structures

Unit 7
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Data Types

A Data Type consists of:
- set of values
- set of operations over those values

Example: Integer
- whole numbers, -32768 to 32767
- +, -, *, /, %, ==, !=, <, >, <=, >=, ...

Which operation is not valid for float?

Data Types (C/C++)

Primitive Data Types
- atomic values, such as:
  - Integers:
    - short, int, long, char, bool
  - Floating Points:
    - float, double, long double

Composite (or Aggregate) Types:
- values of these types are composed from other values.
  - Arrays: sequence of values of the same type
  - Structures: named components of various types

11.2 Structures

Composite data type used to group multiple variables together into a unit.

Example: student
- ID Number
- Name
- Age
- Major

Each student has a value for each of these variables (or attributes).
**Structures in C++**

- Define the student as a struct in C++:

  ```
  struct Student {
    int idNumber;
    string name;
    int age;
    string major;
  };
  ```

- NOTE: semicolon after last curly bracket!
- A struct is a **data type**, and by convention the name is capitalized.
- The components are called “members” (or “fields”).

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**Declaring structure variables**

- So far we have defined a new data type, but we haven’t declared any variables of that type.
- To declare a variable of type Student:

  ```
  Student myStudent;
  ```

- Can declare multiple variables of type Student:

  ```
  Student student1, student2, aGradStudent;
  ```

- Each one has its own set of the member variables in the Student data type

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**Defining structure variables**

- Each variable of type Student has its own set of the member variables from the Student data type

  ```
  Student student1, student2;
  ```

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**11.3 Accessing Structure Members**

- Use dot operator to access members of a struct variable:

  ```
  student1.age = 18;
  student2.idNumber = 123456;
  cin >> aGradStudent.name;
  aGradStudent.major = "Rocket Science";
  ```

- Member variables of structures can be used just like regular variables of the same type.

  ```
  student1.age++;  //happy birthday
  myFunc(student2.idNumber);
  if (student1.age==student2.age) {
    ...
  }
  ```
Operations over structures:

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

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

- How is this different from Arrays?

Assignment (copying) structure variables

- Input the members one at a time:
  ```
  cin >> student1.idNumber;
  cin >> student1.name;
  cin >> student1.age;
  cin >> student1.major;
  ```

- Copy data from student1 into student2:
  ```
  student2 = student1; //copies all 4 values at once!!
  ```

- The above statement is valid, and the same as this:
  ```
  student2.idNumber = student1.idNumber;
  student2.name = student1.name;
  student2.age = student1.age;
  student2.major = student1.major;
  ```

Outputting & comparing structure variables

- Output the members one at a time:
  ```
  cout << student1.idNumber << " ";
  cout << student1.name << " ";
  cout << student1.age << " ";
  cout << student1.major << endl;
  ```

  Output: 11122 Chris Johnson 19 Chemistry

- Comparing two structs:
  ```
  if (student1.idNumber == student2.idNumber &&
      student1.name == student2.name &&
      student1.age == student2.age &&
      student1.major == student2.major)
  ...
  ```

11.4 Initializing a Structure

- Struct variable can be initialized when it is defined:
  ```
  Student student1 = {123456,"John Smith",22, "Math"};
  ```

- Must give values of members in order of the struct declaration.

- Can NOT initialize members in structure declaration, only variable definition:
  ```
  struct StudentA {
      int id = 123456;    //ILLEGAL
      string name = "John Smith";  //ILLEGAL
  }
  ```
struct EmployeePay {
    string name;         // Employee name
    int empNum;          // Employee number
    double payRate;      // Hourly pay rate
    double hours;        // Hours worked
    double grossPay;     // Gross pay
};

int main() {
    EmployeePay employee1 = {"Betty Ross", 141, 18.75};
    EmployeePay employee2 = {"Jill Sandburg", 142, 17.50};
    cout << fixed << setprecision(2);
    // Calculate pay for employee1
    cout << "Name: " << employee1.name << endl;
    cout << "Employee Number: " << employee1.empNum << endl;
    cout << "Enter the hours worked by this employee: ";
    cin >> employee1.hours;
    employee1.grossPay = employee1.hours * employee1.payRate;
    cout << "Gross Pay: " << employee1.grossPay << endl << endl;
    // Calculate pay for employee2
    cout << "Name: " << employee2.name << endl;
    cout << "Employee Number: " << employee2.empNum << endl;
    cout << "Enter the hours worked by this employee: ";
    cin >> employee2.hours;
    employee2.grossPay = employee2.hours * employee2.payRate;
    cout << "Gross Pay: " << employee2.grossPay << endl;
}

Sample output from previous program:

Name: Betty Ross
Employee Number: 141
Enter the hours worked by this employee: 40 [Enter]
Gross Pay: 750.00

Name: Jill Sandburg
Employee Number: 142
Enter the hours worked by this employee: 20 [Enter]
Gross Pay: 350.00

11.5 Arrays of Structures

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

• Each student structure is accessible via the subscript notation:
  roster[0] = student1; //copies student1 to first elem.

• Members of structure accessible via dot operator
  cout << roster[0].name << endl;

Arrays of Structures: initialization

• To initialize an array of structs:

```c++
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:

```cpp
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;
}
```

11.6 Nested Structures

- You can nest one structure inside another.

```cpp
struct Address {
    string street;
    string city;
    string state;
    int zip;
};

struct Student {
    int idNumber;
    string name;
    Address homeAddress;
};
```

Nested Structures

- Use dot operator multiple times to get into the nested structure:

```cpp
Student student1;
student1.name = "Bob Lambert";
student1.homeAddress.city = "San Angelo";
student1.homeAddress.state = "TX";
```

- Or set up address structure separately:

```cpp
Address a1;
a1.street = "101 Main St.";
a1.city = "San Angelo";
a1.state = "TX";
a1.zip = 76903;

student1.name = "Bob Lambert";
student1.homeAddress = a1;
```

11.7 Structures as function arguments

- Structure variables may be passed as arguments to functions.

```cpp
void showStudent(Student x) {
    cout << x.idNumber << endl;
    cout << x.name << endl;
    cout << x.age << endl;
    cout << x.major << endl;
}

int main() {
    Student student1;
    //input information about student1 here
    showStudent(student1);
}
```
Structures as function arguments

- By default, structure variables are passed by value (like most variables).
- If the function needs to change the value of a member, the structure variable should be passed by reference.

```cpp
void happyBirthday(Student &s) {
    s.age++;          // or s.age = s.age + 1;
}
```

Arrays of Structures as function arguments

- Arrays of structure may be passed as arguments to functions.

```cpp
double avgAge(Student arr[], int size) {
    int total = 0;
    for (int i=0; i<size; i++)
        total = total + arr[i].age;
    return static_cast<double>(total)/size;
}
```

11.8 Returning a Structure from a Function

- A function may return a structure.

```cpp
Student inputStudent(ifstream &fin) {
    Student result;
    fin >> result.idNumber;
    fin >> result.name;
    fin >> result.age;
    fin >> result.major;
    return result;
}
```

```cpp
int main() {
    ifstream inFile;
    inFile.open("students.dat");
    Student student1 = inputStudent(inFile);
    for (int i=0; i<40; i++)
        roster[i] = inputStudent(inFile);
    inFile.close();
}
```

Note: always pass iostreams by reference!!

```cpp
int main() {
    ifstream inDate;
    inDate.open("students.dat");
    Student student1 = inputStudent(inDate);
    for (int i=0; i<40; i++)
        roster[i] = inputStudent(inDate);
    inDate.close();
}
```

Note: Student declaration must be global!!

Note: works for an array of any (provided) size