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”).

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:

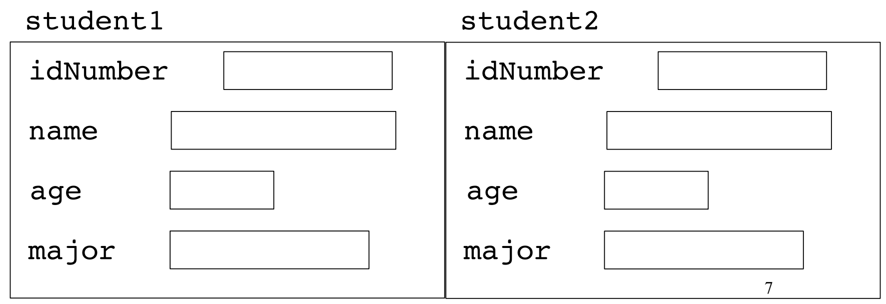
```
Student student1, student2, aGradStudent;
```

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

Defining structure variables

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

```
Student student1, student2;
```



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;
}
```

Initializes only name, empNum, and payRate

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:

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

int main()
{
    Student roster[] = {
        {123456,"Ann Page",22,"Math"},
        {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;
}
```

11.6 Nested Structures

- You can nest one structure inside another.

```
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:

```
Student student1;
student1.name = “Bob Lambert”;
student1.homeAddress.city = “San Angelo”;
student1.homeAddress.state = “TX”;
```

- Or set up address structure separately:

```
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.

```
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);
}
```

Note: Student declaration must be global!!

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.

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

11.8 Returning a Structure from a Function

- A function may return a structure.

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

<u>Arrays</u> of Structures as function arguments

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

```
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;
}

int main() {
  Student roster[250];  // array of 250 student structures

  //input information about student1 here (see slide 17)

  cout << "Average age is: " << avgAge(roster,250) << end;
}
```

Note: Student declaration must be global!!

Note: works for an array of <u>any</u> (provided) size