Ch 11. Structured Data
(11.2 to 11.8)

CS 1428
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Lecture 24

Data Types

- Data Type:
  - 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++)

- Scalar (or Basic) Data Types (atomic values)
  - Arithmetic types
    - Integers
      - short, int, long
      - char, bool
    - Floating points
      - float, double, long double
- Composite (or Aggregate) Types:
  - Arrays: ordered sequence of values of the same type
  - Structures: named components of various types

Structures

- Used to represent a relationship between values of different types
- Example: student
  - ID Number
  - Name
  - Age
  - Major
  - Address
- (the values are related because they belong to the same student)

Structures

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

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

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

Structures

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

```
Student csStudent;
```

- Can define multiple variables of type Student:

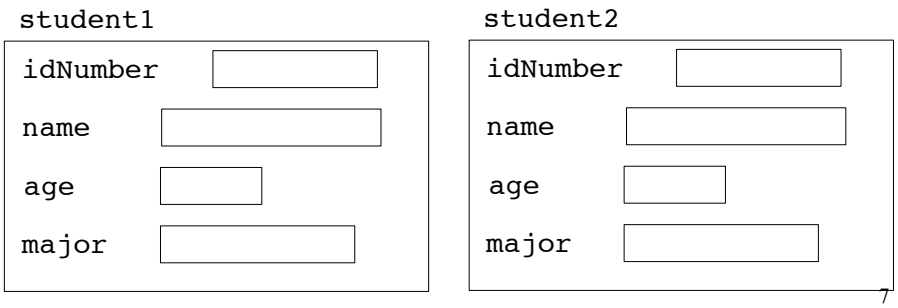
```
Student student1, student2, gradStudent;
```

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

Structures

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

```
Student student1, student2;
```



Accessing Structure Members

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

```
student1.age = 18;
student2.idNumber = 123456;
cin >> gradStudent.name;
gradStudent.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) {
   ...
}
```

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

Structures: output

- 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 Football
```

- Comparing two structs:

```
if (student1.idNumber == student2.idNumber &&
    student1.name == student2.name &&
    student1.age == student2.age &&
    student1.major == student2.major)
...
```

Initializing structures

- Struct variable can be initialized when it is defined:

```
Student student1 = {123456,"John Smith",22, "Math"};
```

- Must give values 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
}
```


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

- Arrays 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;
}
```


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;
```


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;
}

// in 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.

```
void happyBirthday(Student &s) {
   s.age++;
}
```


Returning Structure from 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;
}
// in main:
ifstream inFile;
inFile.open("students.dat");

Student student1 = inputStudent(inFile);
for (int i=0; i<40; i++)
   roster[i] = inputStudent(inFile);

inFile.close();
```

Always pass input/output streams by reference!!

Example: nested Structures

- Could have multiple structs using Address:

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

struct Faculty {
   int idNumber;
   string name;
   string officeLocation;
   Address address;
};
```

```
struct GradStudent {
   int idNumber;
   string name;
   int yearGraduated;
   Address homeAddress;
   Address campusAddr;
};
```


Example: nested Structures

- Could have one function to process Addresses

```
void showAddress(Address x) {
   cout << x.street << endl;
   cout << x.city << ", ";
   cout << x.state << "  ";
   cout << x.zip << endl;
}
```

- Call it for different structure types with Address:

```
Student st;
Faculty fac;
GradStudent gs;
//...
showAddress(st.homeAddress);
showAddress(fac.address);
showAddress(gs.campusAddr);
```

Nested Arrays and Structures

```
struct Course {
  string course;
  int section;
  string title;
  string days;
  string time;
  string bldg;
  int roomNum;
  string instructor;
};
```

```
struct Student {
   int idNumber;
   string name;
   string major;
   Address address;
   Course schedule[10];
   int numCourses;
};
```

```
Student enrolledStudents[35000];
```

```
enrolledStudents[8].schedule[0].course = "CS1428";
```


Initializing arrays of structures

- Provide an initialization list for one or more of the elements in the array:

```
Student roster[40] = {
   {123456,"John Smith",22, "Math"}
   {444555,"Lisa Simpson",18, "Biology"},
   {999999,"Tony Jackson",25, "Physics"},
   {887766,"Melissa Brown",20, "Engineering"}
};
```