EEE110 - Computer Programming
Week 8: Structured Data

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Chapter 11:

Structured Data

11.1

- Abstract Data Types

Abstract Data Types

- A data type that specifies
  - values that can be stored
  - operations that can be done on the values
- User of an abstract data type does not need to know the implementation of the data type, *e.g.*, how the data is stored
- ADTs are created by programmers

Abstraction and Data Types

- Abstraction: a definition that captures general characteristics without details
  - Ex: An abstract triangle is a 3-sided polygon. A specific triangle may be scalene, isosceles, or equilateral
- Data Type defines the values that can be stored in a variable and the operations that can be performed on it

11.2

Combining Data into Structures

Combining Data into Structures

- Structure: C++ construct that allows multiple variables to be grouped together
- General Format:

```
struct <structName>
{
   type1 field1;
   type2 field2;
   . . .
};
```


Example `struct` Declaration

```
struct Student
{
      int studentID;
      string name;
   short yearInSchool;
      double gpa;
};
```

structure tag

structure members

`struct` Declaration Notes

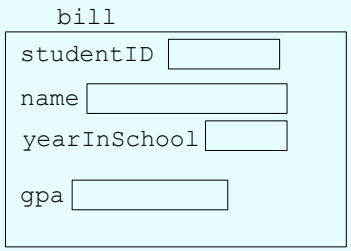
- Must have `;` after closing `}`
- `struct` names commonly begin with uppercase letter
- Multiple fields of same type can be in comma-separated list:

```
string name,
       address;
```


Defining Variables

- `struct` declaration does not allocate memory or create variables
- To define variables, use structure tag as type name:

```
Student bill;
```



11.3

Accessing Structure Members

Accessing Structure Members

- Use the dot `(.)` operator to refer to members of `struct` variables:

```
cin >> stu1.studentID;
getline(cin, stu1.name);
stu1.gpa = 3.75;
```

- Member variables can be used in any manner appropriate for their data type

Program 11-1

```
1  // This program demonstrates the use of structures.
2  #include <iostream>
3  #include <string>
4  #include <iomanip>
5  using namespace std;
6
7  struct PayRoll
8  {
9     int empNumber;    // Employee number
10    string name;      // Employee's name
11    double hours;     // Hours worked
12    double payRate;   // Hourly payRate
13    double grossPay;  // Gross pay
14 };
15
16 int main()
17 {
18    PayRoll employee; // employee is a PayRoll structure.
19
20    // Get the employee's number.
21    cout << "Enter the employee's number: ";
22    cin >> employee.empNumber;
23
24    // Get the employee's name.
25    cout << "Enter the employee's name: ";
```



```
26    cin.ignore();  // To skip the remaining '\n' character
27    getline(cin, employee.name);
28
29    // Get the hours worked by the employee.
30    cout << "How many hours did the employee work? ";
31    cin >> employee.hours;
32
33    // Get the employee's hourly pay rate.
34    cout << "What is the employee's hourly payRate? ";
35    cin >> employee.payRate;
36
37    // Calculate the employee's gross pay.
38    employee.grossPay = employee.hours * employee.payRate;
39
40    // Display the employee data.
41    cout << "Here is the employee's payroll data:\n";
42    cout << "Name: " << employee.name << endl;
43    cout << "Number: " << employee.empNumber << endl;
44    cout << "Hours worked: " << employee.hours << endl;
45    cout << "Hourly payRate: " << employee.payRate << endl;
46    cout << fixed << showpoint << setprecision(2);
47    cout << "Gross Pay: $" << employee.grossPay << endl;
48    return 0;
49 }
```


Program Output with Example Input Shown in Bold

```
Enter the employee's number: 489 [Enter]
Enter the employee's name: Jill Smith [Enter]
How many hours did the employee work? 40 [Enter]
What is the employee's hourly pay rate? 20 [Enter]
Here is the employee's payroll data:
Name: Jill Smith
Number: 489
Hours worked: 40
Hourly pay rate: 20
Gross pay: $800.00
```


Displaying a `struct` Variable

- To display the contents of a `struct` variable, must display each field separately, using the dot operator:

```
cout << bill; // won't work
cout << bill.studentID << endl;
cout << bill.name << endl;
cout << bill.yearInSchool;
cout << " " << bill.gpa;
```

Comparing `struct` Variables

- Cannot compare `struct` variables directly:

```
if (bill == william) // won't work
```

- Instead, must compare on a field basis:

```
if (bill.studentID ==

  william.studentID) ...
```


11.4

Initializing a Structure

Initializing a Structure

- `struct` variable can be initialized when defined:

```
Student s = {11465, "Joan", 2, 3.75};
```

- Can also be initialized member-by-member after definition:

```
s.name = "Joan";
s.gpa = 3.75;
```


More on Initializing a Structure

- May initialize only some members:

```
Student bill = {14579};
```

- Cannot skip over members:

```
Student s = {1234, "John", ,
                    2.83}; //
  illegal
```

- Cannot initialize in the structure declaration, since this does not allocate memory

Excerpts From Program 11-3

```
 8  struct EmployeePay
 9  {
10     string name;          // Employee name
11     int empNum;           // Employee number
12     double payRate;       // Hourly pay rate
13     double hours;         // Hours worked
14     double grossPay;      // Gross pay
15  };
```

```
19     EmployeePay employee1 = {"Betty Ross", 141, 18.75};
20     EmployeePay employee2 = {"Jill Sandburg", 142, 17.50};
```


11.5

Arrays of Structures

Arrays of Structures

- Structures can be defined in arrays
- Can be used in place of parallel arrays
  `const int NUM_STUDENTS = 20;`
  `Student stuList[NUM_STUDENTS];`
- Individual structures accessible using subscript notation
- Fields within structures accessible using dot notation:
  `cout << stuList[5].studentID;`

Program 11-4

```
 1  // This program uses an array of structures.
 2  #include <iostream>
 3  #include <iomanip>
 4  using namespace std;
 5
 6  struct PayInfo
 7  {
 8     int hours;         // Hours worked
 9     double payRate;    // Hourly pay rate
10  };
11
12  int main()
13  {
14     const int NUM_WORKERS = 3;     // Number of workers
15     PayInfo workers[NUM_WORKERS]; // Array of structures
16     int index;                    // Loop counter
17
```

```
18    // Get employee pay data.
19    cout << "Enter the hours worked by " << NUM_WORKERS
20         << " employees and their hourly rates.\n";
21
22    for (index = 0; index < NUM_WORKERS; index++)
23    {
24       // Get the hours worked by an employee.
25       cout << "Hours worked by employee #" << (index + 1);
26       cout << ": ";
27       cin >> workers[index].hours;
28
29       // Get the employee's hourly pay rate.
30       cout << "Hourly pay rate for employee #";
31       cout << (index + 1) << ": ";
32       cin >> workers[index].payRate;
33       cout << endl;
34    }
35
36    // Display each employee's gross pay.
37    cout << "Here is the gross pay for each employee:\n";
38    cout << fixed << showpoint << setprecision(2);
39    for (index = 0; index < NUM_WORKERS; index++)
40    {
41       double gross;
42       gross = workers[index].hours * workers[index].payRate;
43       cout << "Employee #" << (index + 1);
44       cout << ": $" << gross << endl;
45    }
46    return 0;
47 }
```


Program Output with Example Input Shown in Bold

```
Enter the hours worked by 3 employees and their hourly rates.
Hours worked by employee #1: 10 [Enter]
Hourly pay rate for employee #1: 9.75 [Enter]

Hours worked by employee #2: 20 [Enter]
Hourly pay rate for employee #2: 10.00 [Enter]

Hours worked by employee #3: 40 [Enter]
Hourly pay rate for employee #3: 20.00 [Enter]

Here is the gross pay for each employee:
Employee #1: $97.50
Employee #2: $200.00
Employee #3: $800.00
```


11.6

Nested Structures

Nested Structures

A structure can contain another structure as a member:

```
struct PersonInfo
{    string name,
                address,
                city;
};
struct Student
{    int studentID;
          PersonInfo pData;
          short yearInSchool;
          double gpa;
};
```

Members of Nested Structures

- Use the dot operator multiple times to refer to fields of nested structures:

```
Student s;
s.pData.name = "Joanne";
s.pData.city = "Tulsa";
```


11.7

Structures as Function Arguments

Structures as Function Arguments

- May pass members of `struct` variables to functions:
  `computeGPA(stu.gpa);`
- May pass entire `struct` variables to functions:
  `showData(stu);`
- Can use reference parameter if function needs to modify contents of structure variable

Excerpts from Program 11-6

```
 8  struct InventoryItem
 9  {
10     int partNum;                 // Part number
11     string description;          // Item description
12     int onHand;                  // Units on hand
13     double price;                // Unit price
14  };
```

```
61  void showItem(InventoryItem p)
62  {
63     cout << fixed << showpoint << setprecision(2);
64     cout << "Part Number: " << p.partNum << endl;
65     cout << "Description: " << p.description << endl;
66     cout << "Units On Hand: " << p.onHand << endl;
67     cout << "Price: $" << p.price << endl;
68  }
```

Structures as Function Arguments - Notes

- Using value parameter for structure can slow down a program, waste space
- Using a reference parameter will speed up program, but function may change data in structure
- Using a `const` reference parameter allows read-only access to reference parameter, does not waste space, speed

Revised `showItem` Function

```
void showItem(const InventoryItem &p)
{
   cout << fixed << showpoint << setprecision(2);
   cout << "Part Number: " << p.partNum << endl;
   cout << "Description: " << p.description << endl;
   cout << "Units On Hand: " << p.onHand << endl;
   cout << "Price: $" << p.price << endl;
}
```


11.8

Returning a Structure from a Function

Returning a Structure from a Function

- Function can return a `struct`:

```
Student getStudentData();  // prototype
stu1 = getStudentData();   // call
```

- Function must define a local structure
  - for internal use
  - for use with `return` statement

Returning a Structure from a Function - Example

```
Student getStudentData()
{    Student tempStu;
     cin >> tempStu.studentID;
     getline(cin, tempStu.pData.name);
     getline(cin, tempStu.pData.address);
    getline(cin, tempStu.pData.city);
    cin >> tempStu.yearInSchool;
    cin >> tempStu.gpa;
    return tempStu;
}
```


Program 11-7

```
// This program uses a function to return a structure. This
// is a modification of Program 11-2.
#include <iostream>
#include <iomanip>
#include <cmath>  // For the pow function
using namespace std;

// Constant for pi.
const double PI = 3.14159;

// Structure declaration
struct Circle
{
   double radius;      // A circle's radius
   double diameter;    // A circle's diameter
   double area;        // A circle's area
};

// Function prototype
Circle getInfo();

int main()
{
   Circle c;      // Define a structure variable
```



```

   // Get data about the circle.
   c = getInfo();

   // Calculate the circle's area.
   c.area = PI * pow(c.radius, 2.0);

   // Display the circle data.
   cout << "The radius and area of the circle are:\n";
   cout << fixed << setprecision(2);
   cout << "Radius: " << c.radius << endl;
   cout << "Area: " << c.area << endl;
   return 0;
}

```



```
//*************************************************************
// Definition of function getInfo. This function uses a local   *
// variable, tempCircle, which is a circle structure. The user  *
// enters the diameter of the circle, which is stored in        *
// tempCircle.diameter. The function then calculates the radius *
// which is stored in tempCircle.radius. tempCircle is then     *
// returned from the function.                                  *
//*************************************************************

Circle getInfo()
{
   Circle tempCircle;  // Temporary structure variable

   // Store circle data in the temporary variable.
   cout << "Enter the diameter of a circle: ";
   cin >> tempCircle.diameter;
   tempCircle.radius = tempCircle.diameter / 2.0;

   // Return the temporary variable.
   return tempCircle;
}
```

Program Output with Example Input Shown in Bold

```
Enter the diameter of a circle: 10 [Enter]
The radius and area of the circle are:
Radius: 5.00
Area: 78.54
```

11.9

Pointers to Structures

Pointers to Structures

- A structure variable has an address
- Pointers to structures are variables that can hold the address of a structure:
  `Student *stuPtr;`
- Can use `&` operator to assign address:
  `stuPtr = & stu1;`
- Structure pointer can be a function parameter

Accessing Structure Members via Pointer Variables

- Must use `()` to dereference pointer variable, not field within structure:
  `cout << (*stuPtr).studentID;`
- Can use structure pointer operator to eliminate `()` and use clearer notation:
  `cout << stuPtr->studentID;`

From Program 11-8

```
42  void getData(Student *s)
43  {
44     // Get the student name.
45     cout << "Student name: ";
46     getline(cin, s->name);
47
48     // Get the student ID number.
49     cout << "Student ID Number: ";
50     cin >> s->idNum;
51
52     // Get the credit hours enrolled.
53     cout << "Credit Hours Enrolled: ";
54     cin >> s->creditHours;
55
56     // Get the GPA.
57     cout << "Current GPA: ";
58     cin >> s->gpa;
59  }
```

11.11

Unions

Unions

- Similar to a `struct`, but
  - all members share a single memory location, and
  - only one member of the union can be used at a time
- Declared using `union`, otherwise the same as `struct`
- Variables defined as for `struct` variables

Anonymous Union

- A `union` without a union tag:

```
union { ... };
```

- Must use `static` if declared outside of a function
- Allocates memory at declaration time
- Can refer to members directly without dot operator
- Uses only one memory location, saves space

11.12

Enumerated Data Types

Enumerated Data Types

- An enumerated data type is a programmer-defined data type. It consists of values known as *enumerators*, which represent integer constants.

Enumerated Data Types

- Example:

```
enum Day { MONDAY, TUESDAY,
           WEDNESDAY, THURSDAY,
           FRIDAY };
```

- The identifiers `MONDAY`, `TUESDAY`, `WEDNESDAY`, `THURSDAY`, and `FRIDAY`, which are listed inside the braces, are *enumerators*. They represent the values that belong to the `Day` data type.

Enumerated Data Types

```
enum Day { MONDAY, TUESDAY,
           WEDNESDAY, THURSDAY,
           FRIDAY };
```

Note that the enumerators are not strings, so they aren't enclosed in quotes. They are identifiers.

Enumerated Data Types

- Once you have created an enumerated data type in your program, you can define variables of that type. Example:

```
Day workDay;
```

- This statement defines `workDay` as a variable of the `Day` type.

Enumerated Data Types

- We may assign any of the enumerators `MONDAY`, `TUESDAY`, `WEDNESDAY`, `THURSDAY`, or `FRIDAY` to a variable of the `Day` type. Example:

```
workDay = WEDNESDAY;
```


Enumerated Data Types

- So, what is an *enumerator*?
- Think of it as an integer named constant
- Internally, the compiler assigns integer values to the enumerators, beginning at 0.

Enumerated Data Types

```
enum Day { MONDAY, TUESDAY,
           WEDNESDAY, THURSDAY,
           FRIDAY };
```

In memory...

`MONDAY` = 0
`TUESDAY` = 1
`WEDNESDAY` = 2
`THURSDAY` = 3
`FRIDAY` = 4

Enumerated Data Types

- Using the `Day` declaration, the following code...

```
cout << MONDAY << " "
     << WEDNESDAY << " “
     << FRIDAY << endl;
```

...will produce this output:

```
0 2 4
```

Assigning an integer to an `enum` Variable

- You cannot directly assign an integer value to an `enum` variable. This will not work:

```
workDay = 3;  // Error!
```

- Instead, you must cast the integer:

```
workDay = static_cast<Day>(3);
```


Assigning an Enumerator to an `int` Variable

- You CAN assign an enumerator to an `int` variable. For example:

```
int x;
x = THURSDAY;
```

- This code assigns 3 to `x`.

Comparing Enumerator Values

- Enumerator values can be compared using the relational operators. For example, using the `Day` data type the following code will display the message "Friday is greater than Monday.“

```
if (FRIDAY > MONDAY)
{
   cout << "Friday is greater "
        << "than Monday.\n";
 }
```


Program 11-12

```
1  // This program demonstrates an enumerated data type.
2  #include <iostream>
3  #include <iomanip>
4  using namespace std;
5
6  enum Day { MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY };
7
8  int main()
9  {
10    const int NUM_DAYS = 5;    // The number of days
11    double sales[NUM_DAYS];    // To hold sales for each day
12    double total = 0.0;        // Accumulator
13    int index;                 // Loop counter
14
15    // Get the sales for each day.
16    for (index = MONDAY; index <= FRIDAY; index++)
17    {
18       cout << "Enter the sales for day "
19            << index << ": ";
20       cin >> sales[index];
21    }
22
```

Program 11-12 (Continued)

```
23      // Calculate the total sales.
24      for (index = MONDAY; index <= FRIDAY; index++)
25         total += sales[index];
26
27      // Display the total.
28      cout << "The total sales are $" << setprecision(2)
29           << fixed << total << endl;
30
31      return 0;
32   }
```

Program Output with Example Input Shown in Bold

```
Enter the sales for day 0: 1525.00 [Enter]
Enter the sales for day 1: 1896.50 [Enter]
Enter the sales for day 2: 1975.63 [Enter]
Enter the sales for day 3: 1678.33 [Enter]
Enter the sales for day 4: 1498.52 [Enter]
The total sales are $8573.98
```


Enumerated Data Types

- Program 11-12 shows enumerators used to control a loop:

```
// Get the sales for each day.
for (index = MONDAY; index <= FRIDAY;
index++)
{
   cout << "Enter the sales for day "
           << index << ": ";
      cin >> sales[index];
}
```


Anonymous Enumerated Types

- An *anonymous enumerated type* is simply one that does not have a name. For example, in Program 11-13 we could have declared the enumerated type as:

```
enum { MONDAY, TUESDAY,
       WEDNESDAY, THURSDAY,
       FRIDAY };
```


Using Math Operators with `enum` Variables

- You can run into problems when trying to perform math operations with `enum` variables. For example:

```
Day day1, day2; // Define two Day variables.
day1 = TUESDAY; // Assign TUESDAY to day1.
day2 = day1 + 1;// ERROR! Will not work!
```

- The third statement will not work because the expression `day1 + 1` results in the integer value 2, and you cannot store an int in an `enum` variable.

Using Math Operators with `enum` Variables

- You can fix this by using a cast to explicitly convert the result to `Day`, as shown here:

```
// This will work.
day2 = static_cast<Day>(day1 + 1);
```


Using an `enum` Variable to Step through an Array's Elements

- Because enumerators are stored in memory as integers, you can use them as array subscripts. For example:

```
enum Day { MONDAY, TUESDAY, WEDNESDAY,
           THURSDAY, FRIDAY };
const int NUM_DAYS = 5;
double sales[NUM_DAYS];
sales[MONDAY] = 1525.0;
sales[TUESDAY] = 1896.5;
sales[WEDNESDAY] = 1975.63;
sales[THURSDAY] = 1678.33;
sales[FRIDAY] = 1498.52;
```


Using an `enum` Variable to Step through an Array's Elements

- Remember, though, you cannot use the ++ operator on an `enum` variable. So, the following loop will NOT work.

```
Day workDay;  // Define a Day variable
// ERROR!!! This code will NOT work.
for (workDay = MONDAY; workDay <= FRIDAY; workDay++)
{
   cout << "Enter the sales for day "
        << workDay << ": ";
   cin >> sales[workDay];
}
```


Using an `enum` Variable to Step through an Array's Elements

- You must rewrite the loop's update expression using a cast instead of ++:

```
for (workDay = MONDAY; workDay <= FRIDAY;
            workDay = static_cast<Day>(workDay + 1))
{
   cout << "Enter the sales for day "
        << workDay << ": ";
   cin >> sales[workDay];
}
```

Program 11-13

```
1  // This program demonstrates an enumerated data type.
2  #include <iostream>
3  #include <iomanip>
4  using namespace std;
5
6  enum Day { MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY };
7
8  int main()
9  {
10    const int NUM_DAYS = 5;     // The number of days
11    double sales[NUM_DAYS];     // To hold sales for each day
12    double total = 0.0;         // Accumulator
13    Day workDay;                // Loop counter
14
```


Program 11-13 *(continued)*

```
15    // Get the sales for each day.
16    for (workDay = MONDAY; workDay <= FRIDAY;
17                           workDay = static_cast<Day>(workDay + 1))
18    {
19       cout << "Enter the sales for day "
20            << workDay << ": ";
21       cin >> sales[workDay];
22    }
23
24    // Calculate the total sales.
25    for (workDay = MONDAY; workDay <= FRIDAY;
26                           workDay = static_cast<Day>(workDay + 1))
27       total += sales[workDay];
28
29    // Display the total.
30    cout << "The total sales are $" << setprecision(2)
31         << fixed << total << endl;
32
33    return 0;
34 }
```

Program Output with Example Input Shown in Bold

```
Enter the sales for day 0: 1525.00 [Enter]
Enter the sales for day 1: 1896.50 [Enter]
Enter the sales for day 2: 1975.63 [Enter]
Enter the sales for day 3: 1678.33 [Enter]
Enter the sales for day 4: 1498.52 [Enter]
The total sales are $8573.98
```


Enumerators Must Be Unique Within the same Scope

- Enumerators must be unique within the same scope. For example, an error will result if both of the following enumerated types are declared within the same scope:

```
enum Presidents { MCKINLEY, ROOSEVELT, TAFT };

enum VicePresidents { ROOSEVELT, FAIRBANKS,
                      SHERMAN };
```

`ROOSEVELT` is declared twice.

Declaring the Type and Defining the Variables in One Statement

- You can declare an enumerated data type and define one or more variables of the type in the same statement. For example:

```
enum Car { PORSCHE, FERRARI, JAGUAR } sportsCar;
```

This code declares the `Car` data type and defines a variable named `sportsCar`.