ENGINEERING PROGRAMMING I

Chapter 07: Class and OOP

2017

Topics

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Abstract Data Types

- ADT = Programmer-created data types
  - ADT specifies values and operations
    - Values: member variables
    - Operations: member functions
  - ADTs in C++: struct and class

- The user of an abstract data type (ADT) does not need to know any implementation details
  - *e.g.*, how the data is stored or how the functions are carried out
  - E.g.) string type in C++
    - You don't need to know how **`substr()`**, **`compare()`** are implemented.

Object-Oriented Programming

- Procedural programming uses variables to store data, focuses on the processes/ functions that occur in a program. Data and functions are separate and distinct.
- Object-oriented programming is based on objects that encapsulate the data and the functions that operate on it.

Object-Oriented Programming Terminology

- **object**: software entity that combines data and functions that act on the data in a single unit

- **attributes**: the data items of an object, stored in **member variables**

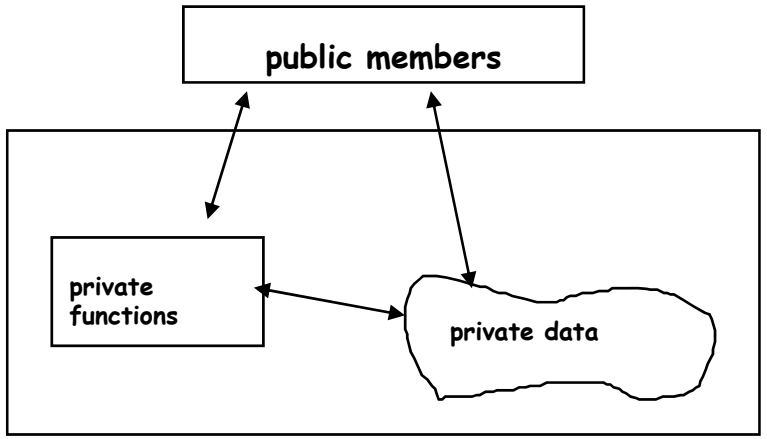
- **member functions (methods)**: procedures/ functions that act on the attributes of the class

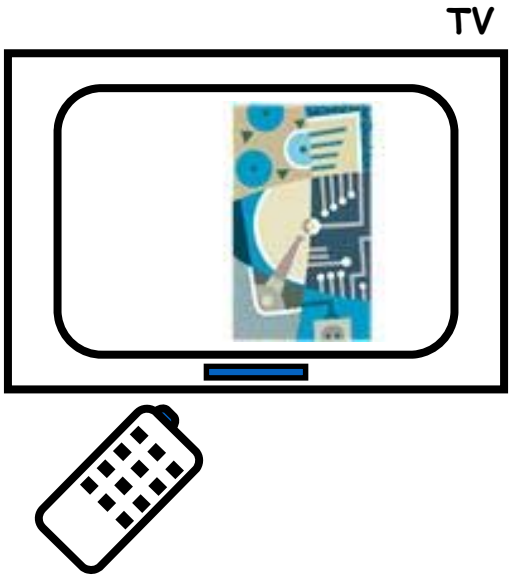
Object-Oriented Terminology

- A programming language is called OOP if it supports
  - **Encapsulation**
  - **Inheritance**
    - Ability to create a new class data type from an existing class.
    - I.e., we can crate a class "Dog" from an existing class "Animal"
    - Purpose of inheritance is reusability.
  - **Polymorphism**
    - Ability to take on many forms.
    - Harry is a dog, and it is also an animal.
  - EP1 will not cover inheritance and polymorphism.
    - If interested, please take Object Oriented Programming class (CSE241) in Computer Science major.

Encapsulation

- Encapsulation requires functions, modules and classes
  - Hide implementation details
  - Have clearly defined external interfaces

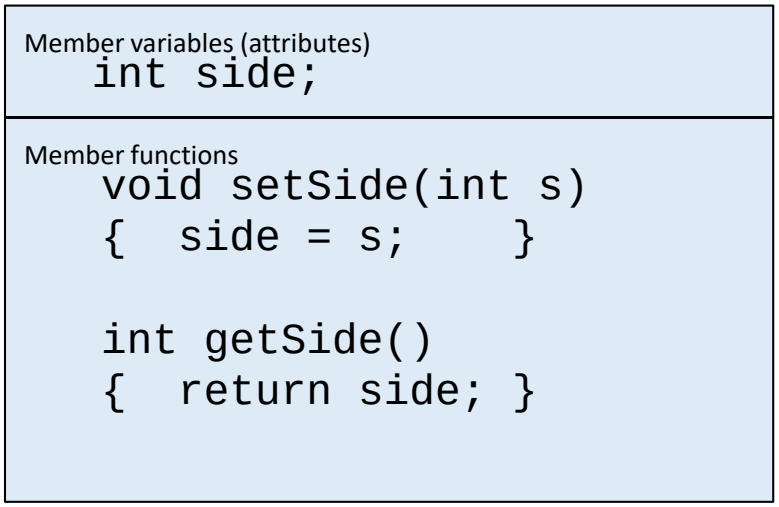




- Also referred to as "data hiding".
  - "data hiding" prevents inadvertent data modification

Object Example

Square



Square object's data item: **`side`**

Square object's functions: **`setSide`** - set the size of the side of the square,

`getSide` - return the size of the side of the square

Introduction to Classes

- **Class**: a programmer-defined datatype used to define objects
- It is a pattern for creating objects
- Class declaration format:

```
class className
{
   declaration;
   declaration;
};
```

Notice the required ;

Access Specifiers

- Used to control access to members of the class.
- Each member is declared to be either

  `public`: can be accessed by functions outside of the class

  or

  `private`: can only be called by or accessed by functions that are members of the class

Class Example


```
class Square
{
  private:
    int side;
  public:
    void setSide(int s)
    { side = s; }
    int getSide()
    { return side; }
};
```

More on Access Specifiers

- Can be listed in any order in a class
- Can appear multiple times in a class
- If not specified, the default is **`private`**

Introduction to Objects

- An object is an instance of a class
- Defined just like other variables

```
Square sq1, sq2;
```

- Can access members using dot operator

```
sq1.setSide(5);
cout << sq1.getSide();
```

Types of Member Functions

- **Acessor, get, getter function**: uses but does not modify a member variable

  ex: **`getSide`**

- **Mutator, set, setter function**: modifies a member variable

  ex: **`setSide`**

Defining Member Functions

- Member functions are part of a class declaration
- Can place entire function definition inside the class declaration

  or
- Can place just the prototype inside the class declaration and write the function definition after the class

Defining Member Functions Inside the Class Declaration

- Member functions defined inside the class declaration are called inline functions
- Only very short functions, like the one below, should be inline functions

```
int getSide()
{ return side; }
```

Inline Member Function Example

```
class Square
{
  private:
    int side;
  public:
    void setSide(int s)
    { side = s; }
    int getSide()
    { return side; }
};
```

Defining Member Functions After the Class Declaration

- Put a function prototype in the class declaration
- In the function definition, precede function name with class name and scope resolution operator (::)

```
int Square::getSide()
{
  return side;
}
```

Conventions and a Suggestion

- Conventions:
- Member variables are usually private
- Accessor and mutator functions are usually public
- Use 'get' in the name of accessor functions, 'set' in the name of mutator functions

- Suggestion: calculate values to be returned in accessor functions when possible, to minimize the potential for stale data

Tradeoffs of Inline vs. Regular Member Functions

- When a regular function is called, control passes to the called function
  - the compiler stores return address of call, allocates memory for local variables, etc.
- Code for an inline function is copied into the program in place of the call when the program is compiled
  - larger executable program, but
  - less function call overhead, possibly faster execution

Constructors

- A **constructor** is a member function that is used to initialize data members of a class
- Is called automatically when an object of the class is created
- Must be a **`public`** member function
- Must be named the same as the class
- Must have no return type

Constructor – 2 Examples

Inline:

```
class Square
{
   . . .
   public:
     Square(int s)
     { side = s; }
   . . .
};
```

Declaration outside the class:

```
Clas Square
{
  Square(int); //prototype
               //in class
}

Square::Square(int s)
{
   side = s;
}
```

Overloading Constructors

- A class can have more than 1 constructor
- Overloaded constructors in a class must have different parameter lists

```
Square();
Square(int);
```

The Default Constructor

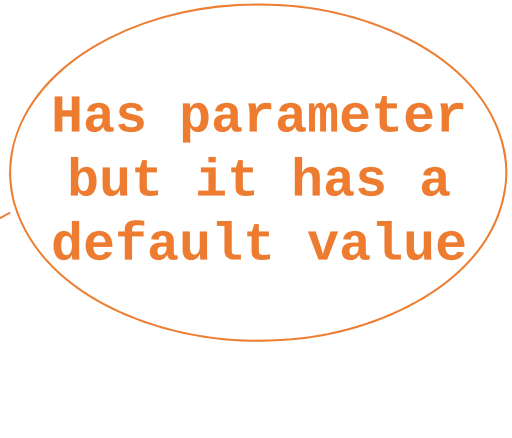
- Constructors can have any number of parameters, including none
- A **default constructor** is one that takes no arguments either due to
  - No parameters or
  - All parameters have default values
- If a class has any programmer-defined constructors, it must have a programmer- defined default constructor

Default Constructor Example

```
class Square
{
  private:
    int side;

  public:
    Square()          // default
    { side = 1; }     // constructor

    // Other member
    // functions go here
};
```

Another Default Constructor Example

```
class Square
{
  private:
    int side;

  public:
    Square(int s = 1) // default
    { side = s; }     // constructor

    // Other member
    // functions go here
};
```



Invoking a Constructor

- To create an object using the default constructor, use no argument list and no **()**

```
Square square1;
```

- To create an object using a constructor that has parameters, include an argument list

```
Square square1(8);
```

Destructors

- Public member function automatically called when an object is destroyed
- Destructor name is ~*className*, *e.g.*, **`~Square`**
- Has no return type
- Takes no arguments
- Only 1 destructor is allowed per class
  (*i.e.*, it cannot be overloaded)

Private Member Functions

- A **`private`** member function can only be called by another member function of the same class
- It is used for internal processing by the class, not for use outside of the class

Passing Objects to Functions

- A class object can be passed as an argument to a function
- When passed by value, function makes a local copy of object. Original object in calling environment is unaffected by actions in function
- When passed by reference, function can use 'set' functions to modify the object.

Notes on Passing Objects

- Using a value parameter for an object can slow down a program and waste space
- Using a reference parameter speeds up program, but allows the function to modify data in the structure
- To save space and time, while protecting structure data that should not be changed, use a **const** reference parameter

```
void showData(const Square &s)
                                  // header
```

Returning an Object from a Function

- A function can return an object

```
Square initSquare();   // prototype
s1 = initSquare();     // call
```

- Function must define a object
  - for internal use
  - to use with **return** statement

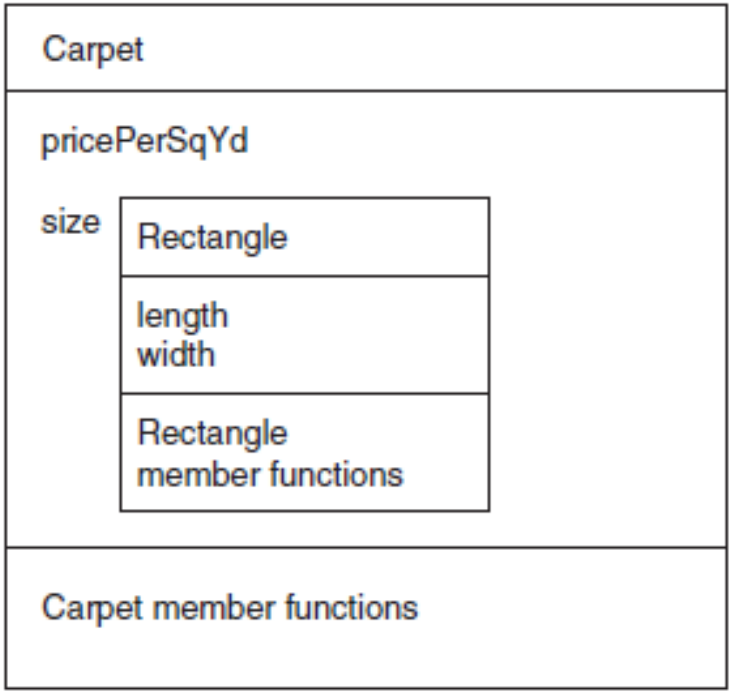
Returning an Object Example

```
Square initSquare()
{
  Square s;    // local variable
  int inputSize;
  cout << "Enter the length of side: ";
  cin >> inputSize;
  s.setSide(inputSize);
  return s;
}
```

Object Composition

- Occurs when an object is a member variable of another object.
- Often used to design complex objects whose members are simpler objects
- ex. (from book): Define a rectangle class. Then, define a carpet class and use a rectangle object as a member of a carpet object.

Object Composition, cont.



Separating Class Specification, Implementation, and Client Code

- Separating class declaration, member function definitions, and the program that uses the class into separate files is considered good design

Using Separate Files

- Place class declaration in a header file that serves as the class specification file. Name the file ***`classname.h`*** (for example, **`Square.h`**)

- Place member function definitions in a class implementation file. Name the file ***`classname.cpp`*** (for example, **`Square.cpp`**) This file should **`#include`** the class specification file.

- A client program (client code) that uses the class must **`#include`** the class specification file and be compiled and linked with the class implementation file.

Include Guards

- Used to prevent a header file from being included twice
- Format:

```
#ifndef symbol_name
#define symbol_name
. . .   (normal contents of header file)
#endif
```

- *symbol_name* is usually the name of the header file, in all capital letters:

```
#ifndef SQUARE_H
#define SQUARE_H
. . .
#endif
```

What Should Be Done Inside vs. Outside the Class

- Class should be designed to provide functions to store and retrieve data
- In general, I/O should be done by functions that use class objects, rather than by class member functions

Input Validation Objects

Classes can be designed to validate user input

- to ensure acceptable menu choice
- to ensure a value is in range of valid values
- etc.

Structures

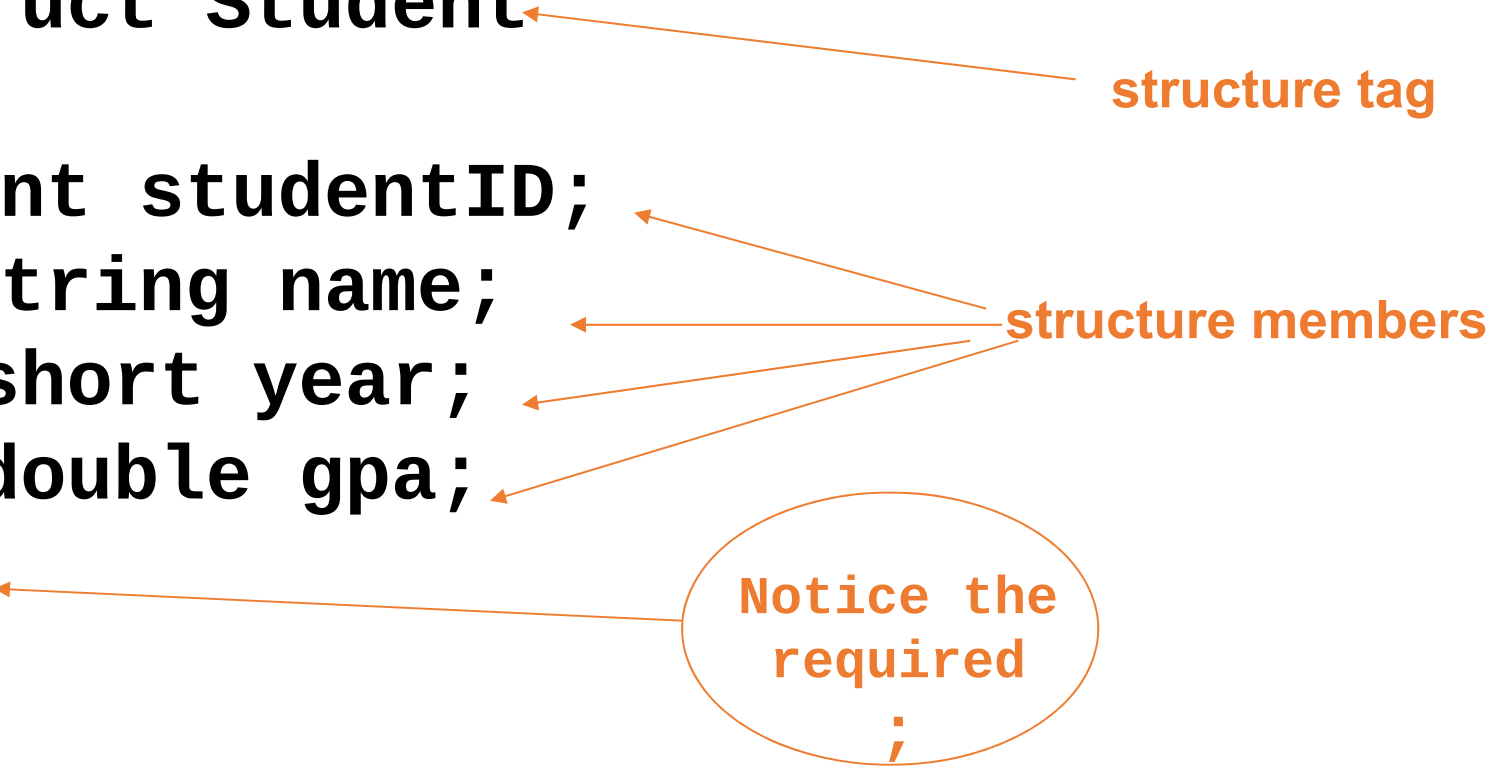
- Structure: C++ construct that allows multiple variables to be grouped together

- Structure Declaration Format:

```
struct structure name
{
 type1 field1;
 type2 field2;
   …
 typen fieldn;
};
```

Example `struct` Declaration

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



`struct` Declaration Notes

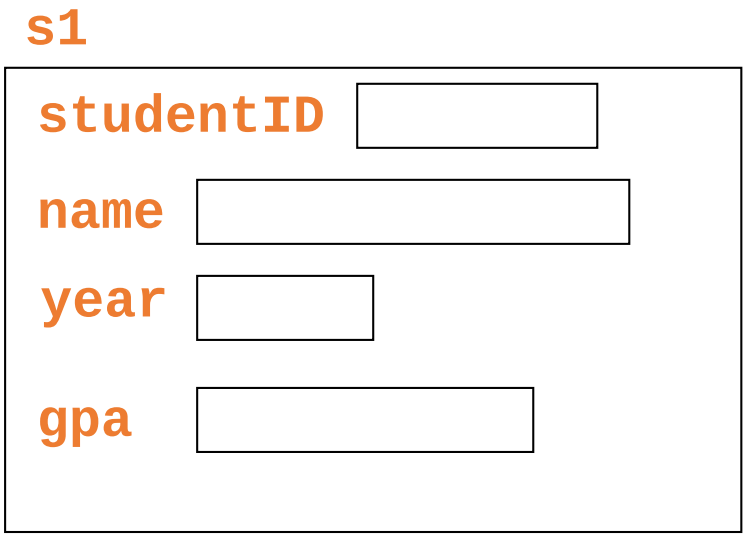
- `struct` names commonly begin with an uppercase letter
- The structure name is also called the tag
- Multiple fields of same type can be in a comma-separated list

```
string name,
       address;
```

Defining Structure Variables

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

```
Student s1;
```



Accessing Structure Members

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

```
getline(cin, s1.name);
cin >> s1.studentID;
s1.gpa = 3.75;
```

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

Displaying `struct` Members

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

Wrong:

```
cout << s1; // won't work!
```

Correct:

```
cout << s1.studentID << endl;
cout << s1.name << endl;
cout << s1.year << endl;
cout << s1.gpa;
```

Comparing `struct` Members

- Similar to displaying a **`struct`**, you cannot compare two **`struct`** variables directly:

```
if (s1 >= s2) // won't work!
```

- Instead, compare member variables:

```
if (s1.gpa >= s2.gpa) // better
```

Initializing a Structure

Cannot initialize members in the structure declaration, because no memory has been allocated yet

```
struct Student      // Illegal
{                   // initialization
  int studentID = 1145;
  string name = "Alex";
  short year = 1;
  float gpa = 2.95;
};
```

Initializing a Structure (continued)

- Structure members are initialized at the time a structure variable is created
- Can initialize a structure variable's members with either
  - an initialization list
  - a constructor

Using an Initialization List

An initialization list is an ordered set of values, separated by commas and contained in { }, that provides initial values for a set of data members

```
{12, 6, 3}  // initialization list
            // with 3 values
```

More on Initialization Lists

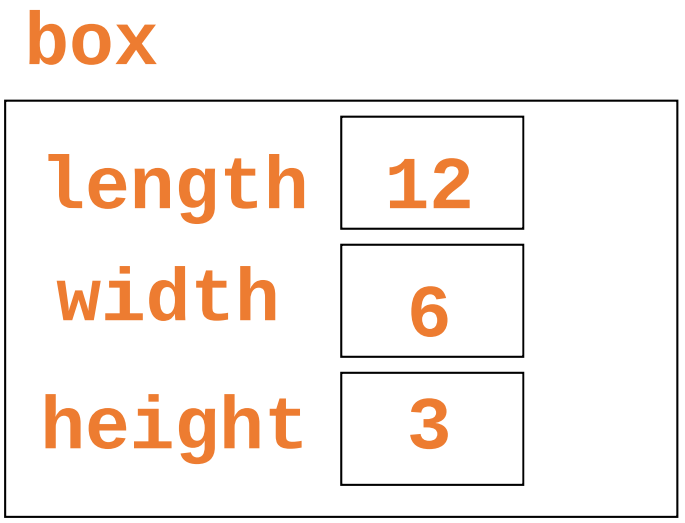
- Order of list elements matters: First value initializes first data member, second value initializes second data member, etc.
- Elements of an initialization list can be constants, variables, or expressions

```
{12, W, L/W + 1} // initialization list
                 // with 3 items
```

Initialization List Example

Structure Declaration

```
struct Dimensions
{
   int length,
       width,
       height;
};
Dimensions box = {12,6,3};
```



Partial Initialization

Can initialize just some members, but cannot skip over members

```
Dimensions box1 = {12,6};  //OK
Dimensions box2 = {12,,3}; //illegal
```

Problems with Initialization List

- Can't omit a value for a member without omitting values for all following members
- Does not work on most modern compilers if the structure contains any string objects
  - Will, however, work with C-string members

Using a Constructor to Initialize Structure Members

- Similar to a constructor for a class:
  - name is the same as the name of the struct
  - no return type
  - used to initialize data members
- It is normally written inside the **`struct`** declaration

A Structure with a Constructor

```
struct Dimensions
{
  int length,
      width,
      height;
  // Constructor
  Dimensions(int L, int W, int H)
  {length = L; width = W; height = H;}
};
```

Passing Arguments to a Constructor

- Create a structure variable and follow its name with an argument list
- Example:

```
Dimensions box3(12, 6, 3);
```

Nested Structures

A structure can have another structure as a member.

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

Members of Nested Structures

Use the dot operator multiple times to access fields of nested structures

```
Student s5;
s5.pData.name = "Joanne";
s5.pData.city = "Tulsa";
```

Structures as Function Arguments

- May pass members of **`struct`** variables to functions

```
computeGPA(s1.gpa);
```

- May pass entire **`struct`** variables to functions

```
showData(s5);
```

- Can use reference parameter if function needs to modify contents of structure variable

Notes on Passing Structures

- Using a value parameter for structure can slow down a program and waste space
- Using a reference parameter speeds up program, but allows the function to modify data in the structure
- To save space and time, while protecting structure data that should not be changed, use a **const** reference parameter

```
void showData(const Student &s)
                                  // header
```

Returning a Structure from a Function

- Function can return a **`struct`**

```
Student getStuData();  // prototype
s1 = getStuData();     // call
```

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

Returning a Structure Example

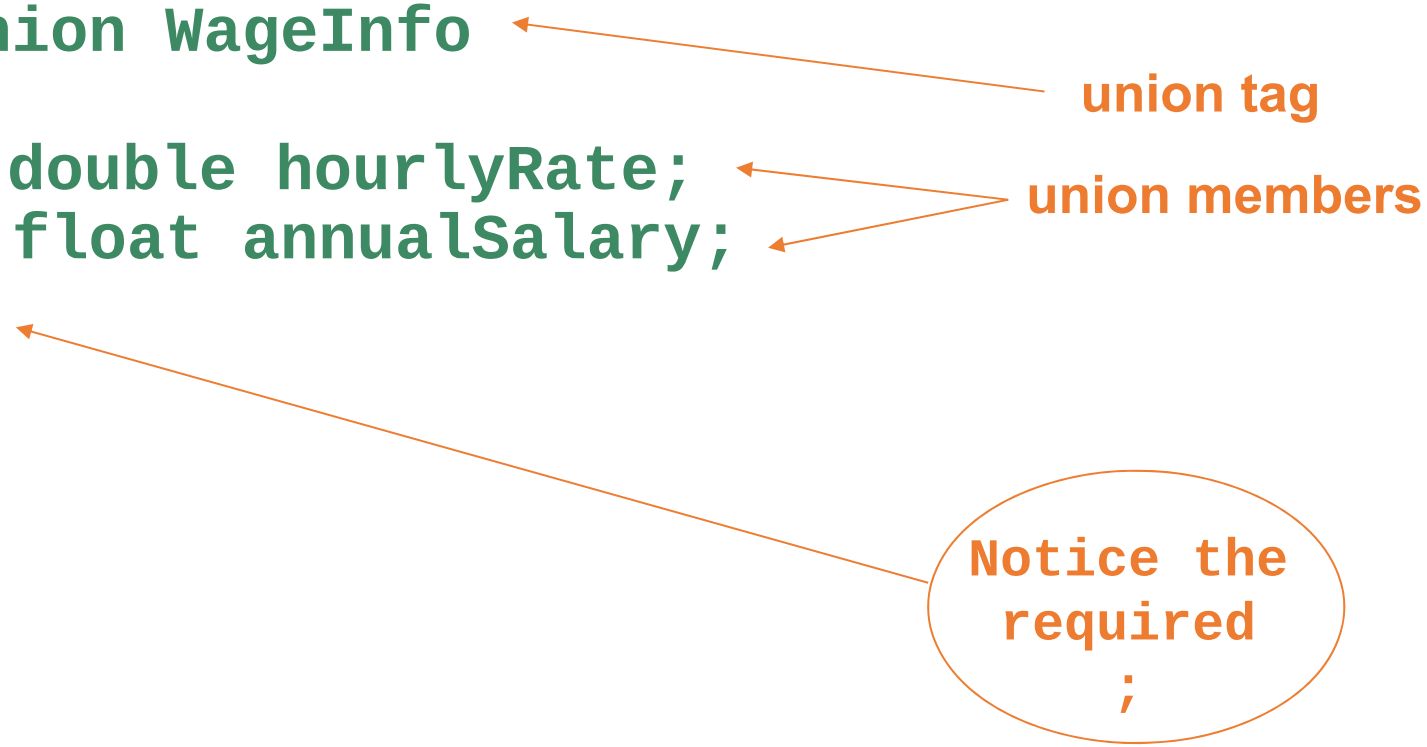
```
Student getStuData()
{ Student s;    // local variable
  cin >> s.studentID;
  cin.ignore();
  getline(cin, s.pData.name);
  getline(cin, s.pData.address);
  getline(cin, s.pData.city);
  cin >> s.year;
  cin >> s.gpa;
  return s;
}
```

Unions

- Similar to a **`struct`**, but
  - all members share a single memory location, which saves space
  - only 1 member of the union can be used at a time
- Declared using key word **`union`**
- Otherwise the same as **`struct`**
- Variables defined and accessed like **`struct`** variables

Example **union** Declaration

```
union WageInfo
{
  double hourlyRate;
  float annualSalary;
};
```



Introduction to Object-Oriented Analysis and Design

- Object-Oriented Analysis: that phase of program development when the program functionality is determined from the requirements
- It includes
  - identification of objects and classes
  - definition of each class's attributes
  - identification of each class's behaviors
  - definition of the relationship between classes

Identify Objects and Classes

- Consider the major data elements and the operations on these elements
- Candidates include
  - user-interface components (menus, text boxes, *etc.*)
  - I/O devices
  - physical objects
  - historical data (employee records, transaction logs, *etc.*)
  - the roles of human participants

Finding the Classes

Technique:

- Write a description of the problem domain (objects, events, etc. related to the problem)
- List the nouns, noun phrases, and pronouns. These are all candidate objects
- Refine the list to include only those objects that are relevant to the problem

Define Class Attributes and Behaviors

- For each class,
  - determine the data elements needed by an object of that class
  - determine the behaviors or activities that the class must perform

Determine Class Responsibilities

Class responsibilities:

- What is the class responsible to know?
- What is the class responsible to do?

Use these to define the member functions

Relationships Between Classes

Possible relationships

- Access ("uses-a")
- Ownership/Composition ("has-a")
- Inheritance ("is-a")

Object Reuse

- A well-defined class can be used to create objects in multiple programs
- By re-using an object definition, program development time is shortened
- One goal of object-oriented programming is to support object reuse