CS100
Introduction to Programming

Lecture 13. Object-Oriented Programming: Encapsulation

Learning objectives

- Understand the difference between
  - Procedural programming
  - Object-Oriented programming
- Understanding the role of a class in C++
- Access specifiers, Constructors & Overloading
- Code organization and compilation in C++

Outline

- Procedural Programming vs OOP
- Classes
  - Example: Morphing from Struct
  - Basics
  - Access
  - Constructors
  - Overloading
- Code organization
- Compilation in C++

Procedural Programming

- In C, everything we've been doing has been ***procedural programming***

- code is divided into multiple procedures
  - procedures operate on data (structures), when given correct number and type of arguments
  - program calls the procedures in sequence

- Example:
  - **`printf(<character array>,<parameters>)`**

Object-Oriented Programming

- now that we start using C++, we can start taking advantage of ***object-oriented programming***

- adding OOP to C was one of the driving forces behind the creation of C++ as a language
  - C++'s predecessor was actually called "C with Classes"

Object-Oriented Programming

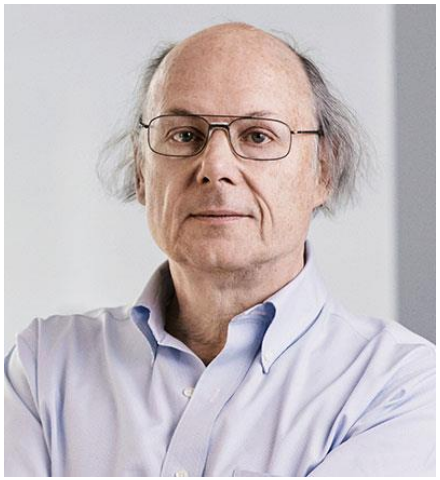
- With lots of data and tasks → unmaintainable
- Idea of OOP:
  - Concept of “interacting objects”
  - Data and procedures specific for an object are “packed away” into neat, self-contained boxes
  - Permits to think of objects more abstractly and focus on their interactions

- C + OOP = C++!

https://www.youtube.com/watch?v=JBjjnqG0BP8

Bjarne Stroutrup

Inventor of C++



Object-Oriented Programming

- in OOP, code and data are combined into a single entity called a ***class***
  - each ***instance*** of a given class is an ***object*** of that class type

- principles of Object-Oriented Programming
  - encapsulation
  - inheritance
  - polymorphism

OOP: Encapsulation

- ***encapsulation*** is a form of information hiding and abstraction
- data and functions that act on that data are grouped together (inside a class)

- *ideal:* separate the interface/implementation so that you can use the former without any knowledge of the latter

OOP: Inheritance

- ***inheritance*** allows us to create and define new classes from an existing class (i.e. sub-classes)

- this allows us to re-use code
  - faster implementation time
  - fewer errors
  - easier to maintain/update

OOP: Polymorphism

- ***polymorphism*** is when a single name can have multiple meanings
  - normally used in conjunction with inheritance
  - ability to decide at runtime what will be done

- We'll look at one form of polymorphism today:
  - overloading functions

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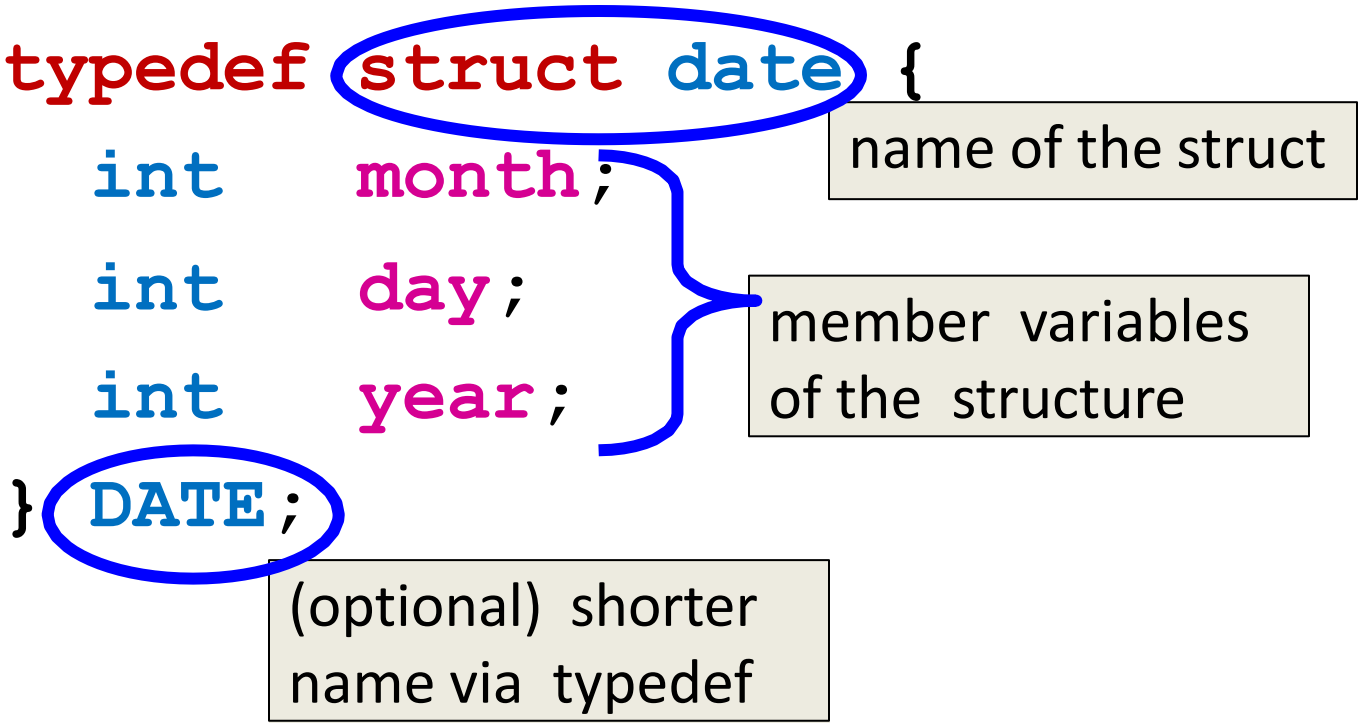
Example Struct: Date



Using a Struct

- if we want to print a date using the struct, what should our function prototype be?

```
void PrintDate(DATE day);
```

- if we want to change the year of a date, what should our function prototype be?

```
void ChangeYear(DATE * day, int year);
```

Morphing from Struct to Class

```
typedef struct date {
   int    month;
   int    day;
   int    year;
} DATE;
```

Morphing from Struct to Class

```
struct date {
   int    month;
   int    day;
   int    year;
};
```

- remove the **`typedef`** – we won't need it for the class

Morphing from Struct to Class

```
class date {
   int    month;
   int    day;
   int    year;
};
```

- change **`struct`** to **`class`**

Morphing from Struct to Class

```
class Date {
   int    month;
   int    day;
   int    year;
};
```

- capitalize date – according to the style guide, classes are capitalized, while structs are not

Morphing from Struct to Class

```
class Date {
   int m_month;
   int m_day;
   int m_year;
};
```

- add **m_** to the variable names – classes are more complicated, this can help prevent confusion about which vars are member vars

Morphing from Struct to Class

```
class Date {
public:
   int m_month;
   int m_day;
   int m_year;
};
```

- make the variables **`public`**,
  to be able to access them
  - by default, members of a class are private

Morphing from Struct to Class

```
class Date {
public:
   int m_month;
   int m_day;
   int m_year;
};
```

- syntax highlighted colors change

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Functions in Classes

- unlike structs, classes have ***member functions*** along with their member variables
  - Note: **`struct`** refers to a C-style **`struct`**. In C++, there is (almost) no difference between **`class`** and **`struct`**

- member functions go <u>inside</u> the class declaration
- member functions are <u>called on</u> an object of that class type

```
iStream.open("file.txt");
```

object method

Example: OutputMonth() Function

- let's add a function to the class that will print out the name of the month

```
class Date {
public:
   int m_month;
   int m_day;
   int m_year;
};
```

Example: OutputMonth()

- let's add a function to the class that will print out the name of the month

```
class Date {
public:
   int m_month;
   int m_day;
   int m_year;
   void OutputMonth();
};
```

function prototype

Example: OutputMonth()

```
void OutputMonth();
```

- nothing is passed in to the function – why?
- because it only needs access to see the variable **`m_month`**
  - which is a ***member variable*** of the Date class
  - just like OutputMonth() is a ***member function***

OutputMonth() Definition

```
void Date::OutputMonth() {




}
```

OutputMonth() Definition

```
void Date::OutputMonth()  {


}
```

specify class name;
more than one class
can have a function
with the same name

OutputMonth() Definition

```
void Date::OutputMonth()  {



}
```

this double colon is called the ***scope resolution operator***, and associates the ***member function*** `OutputMonth()` with the class `Date`

OutputMonth() Definition

```
void Date::OutputMonth() {
   switch (m_month) {
      case 1: printf("January"); break;
      case 2: printf("February"); break;
      case 3: printf("March"); break;
      /* etc */
      default:
         printf("Error in Date::OutputMonth\n");
   }
}
```

OutputMonth() Definition

```
void Date::OutputMonth() {
   switch (m_month) {
      case 1: pr
      case 2: pr
      case 3: pr
      /* etc */
      default:
        printf("Error in Date::OutputMonth\n");
   }
}
```

we can directly access **m_month** because it is a ***member variable*** of the **Date** class, to which **OutputMonth** ( ) belongs

Print Functions

- is the following valid code?

```
printf(today.OutputMonth());
```

- no, because **`OutputMonth()`** returns nothing for **`printf`** to print
  - if the function returned a string, this would be valid code

Using the Date Class

```
Date today;
```

variable **`today`** is an ***instance*** of the class **`Date`**

it is an ***object*** of type **`Date`**

Using the Date Class

```
Date today;


printf("Please enter dates as DD MM YYYY:\n");


printf("Please enter today's date: ");
scanf("%d %d %d", &today.m_day,
      &today.m_month, &today.m_year);
```

when we are not inside the class (as we were in the **`OutputMonth()`** function) we must use the dot operator to access **`today`**'s ***member variables***

Using the Date Class

```
Date today;


printf("Please enter dates as DD MM YYYY:\n");


printf("P
scanf("%d
      &toda

printf("Today's date is ");
today.OutputMonth();
printf("%d, %d\n", today.m_day, today.m_year);
```

We also use the dot operator to call the ***member function*** **`OutputMonth()`** on the **`Date`** object **`today`**

Again, note that we do not need to pass in the ***member variable*** **`m_month`**

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Access Specifiers

- In our definition of the **Date** class, everything was **public** – this is not good practice!

- Why?

Access Specifiers

- We have three different options for ***access specifiers***, each with their own role:
  - public
  - private
  - protected

- specify access for members inside the class

Toy Example

```
class Date {
public:
   int m_month;
private:
   int m_day;
protected:
   int m_year;
};
```

Using Public, Private, Protected

- **`public`**
  - anything that has access to a **`Date`** object also has access to all public member variables and functions

- not normally used for variables;
  used for most functions

- need to have at least one item be public

Using Public, Private, Protected

- **`private`**
  - private members variables and functions can only be accessed by ***member functions*** of the **`Date`** class; cannot be accessed in main(), etc.

- if not specified, members default to private
  - should specify anyway – good coding practices!

Using Public, Private, Protected

- **`protected`**
  - protected member variables and functions can only be accessed by ***member functions*** of the **`Date`** class, and by member functions of any derived classes
  - (we'll cover this later)

Access Specifiers for Date Class

```
class Date {
public:
   void OutputMonth();
private:
   int m_month;
   int m_day;
   int m_year;
};
```

New Member Functions

- now that **`m_month`**, **`m_day`**, and **`m_year`** are ***private***, how do we give them values, or retrieve those values?

New Member Functions

- now that **`m_month`**, **`m_day`**, and **`m_year`** are ***private***, how do we give them values, or retrieve those values?

- write public member functions to provide indirect, controlled access for the user
  - *ideal:* programmer only knows interface (public functions) not implementation (private variables)

Member Function Types

- Many classifications.
- Example:
  - accessor functions
  - mutator functions
  - auxiliary functions

Member Functions: Accessor

- *convention*: start with **`Get`**
- allow retrieval of private data members

- examples:

```
int GetMonth();
int GetDay();
int GetYear();
```

Member Functions: Mutator

- *convention*: start with **`Set`**
- allow changing the value of a private data member

- examples:

```
void SetMonth(int m);
void SetDay(int d);
void SetYear(int y);
```

Member Functions: Auxiliary

- provide support for the operations
  - public if generally called outside function
  - private/protected if only called by member functions

- examples:

```
void OutputMonth();      → public
void IncrementDate();    → private
```

Access Specifiers for Date Class

```
class Date {
public:
   void OutputMonth();
   int  GetMonth();
   int  GetDay();
   int  GetYear();
   void SetMonth(int m);
   void SetDay  (int d);
   void SetYear (int y);
private:
   int m_month;
   int m_day;
   int m_year;
};
```

for the sake of brevity, we'll leave out the accessor and mutator functions from now on

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Constructors

- special ***member functions*** used to create (or "construct") new objects

- automatically called when an object is created
  - implicit: `Date today;`
  - explicit: `Date today(10, 15, 2014);`

- initializes the values of all data members

Date Class Constructors

```
class Date {
public:
   void OutputMonth();
   Date (int m, int d, int y);
private:
   int m_month;
   int m_day;
   int m_year;
};
```

exact same name as the class

Date Class Constructors

```
class Date {
public:
   void OutputMonth();
   Date (int m, int d, int y);
private:
   int m_month;
   int m_day;
   int m_year;
};
```

No return type, not even void

Constructor Definition

```
Date::Date (int m, int d, int y)
{



}
```

Constructor Definition

```
Date::Date (int m, int d, int y)
{
   m_month = m;
   m_day = d;
   m_year = y;
}
```

Constructor Definition

```
Date::Date (int m, int d, int y)
{
    m_month = m;

    m_day = d;


    m_year = y;

}
```

Constructor Definition

```
Date::Date (int m, int d, int y)
{
  if (m > 0 && m <= 12) {
    m_month = m; }
  else { m_month = 1; }
  if (d > 0 && d <= 31) {
    m_day = d; }
  else { m_day = 1; }
  if (y > 0 && y <= 2100) {
    m_year = y; }
  else { m_year = 1; }
}
```

is this the best way to handle this?

what might be a better solution?

Constructor Definition

```
Date::Date (int m, int d, int y)
{
   SetMonth(m);
   SetDay(d);
   SetYear(y);
}
```

→ this allows us to reuse already written code

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Overloading

- we can define multiple versions of the constructor – we can ***overload*** it

- different constructors for:
  - when all values are known
  - when no values are known
  - when some subset of values are known

All Known Values

- have the constructor set user-supplied values

```
Date::Date (int m, int d, int y)
{
   SetMonth(m);
   SetDay(d);
   SetYear(y);
}
```

invoked when constructor is called with all arguments

No Known Values

- have the constructor set all default values

```
Date::Date ()
{
   SetMonth(1);
   SetDay(1);
   SetYear(1);
}
```

invoked when constructor is called with no arguments

Some Known Values

- have the constructor set some default values

```
Date::Date (int m, int d)
{
   SetMonth(m);
   SetDay(d);
   SetYear(1);
}
```

invoked when constructor is called with two arguments

Overloaded Date Constructor

- so far we have the following constructors:

```
Date::Date (int m, int d, int y);
Date::Date (int m, int d);
Date::Date ();
```

Overloaded Date Constructor

- so far we have the following constructors:

```
Date::Date (int m, int d, int y);
Date::Date (int m, int d);
Date::Date ();
```

- would the following be a valid constructor?

```
Date::Date (int m, int y);
```

Avoiding Multiple Constructors

- defining multiple constructors for different sets of known values is a lot of unnecessary code duplication

- we can avoid this by setting ***default parameters*** in our constructors

Default Parameters

- in the ***function prototype*** <u>only</u>, provide default values you want the constructor to use

```
Date (int m      , int d      ,
      int y      );
```

Default Parameters

- in the ***function prototype*** only, provide default values you want the constructor to use

```
Date (int m = 10, int d = 15,
      int y = 2014);
```

Default Parameters

- in the ***function definition*** nothing changes

```
Date::Date (int m, int d, int y) {
   SetMonth(m);
   SetDay(d);
   SetYear(y);
}
```

Using Default Parameters

- the following are all valid declarations:

```
Date graduation(5,18,2015);
Date today;
Date halloween(10,31);
Date july(4);

// graduation: 5/18/2015
// today:      10/15/2014
// halloween:  10/31/2014
// july:       4/15/2014
```

Using Default Parameters

- the following are all valid declarations:

```
Date graduation(5,19,2014);
Date today;
Date hallowe
Date july(4)

// graduation: 5/19/2014
// today:      10/15/2014
// halloween:  10/31/2014
// july:       4/15/2014
```

NOTE: when you call a constructor with no arguments, you do not give it empty parentheses

Default Constructors

- a ***default constructor*** is provided by compiler
  - will handle declarations of **`Date`** instances

- this is how we created **`Date`** objects in the slides before we declared and defined our own constructor

Default Constructors

- **but**, if you create **any** other constructor, the compiler doesn't provide a default constructor

- so if you create a constructor, make a default constructor too, even if its body is just empty

```
Date::Date ()
{
   /* empty */
}
```

Function Overloading

- functions in C++ are uniquely identified by both their names and their parameters
  - **but NOT their return type!**

- we can overload any kind of function
  - we can even use default values, like with constructors

Overloading Example

```
void PrintMessage (void) {
  printf("Hello World!");
}

void PrintMessage (string msg) {
  printf(msg.c_str());
}
```

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Code organization

- Header: Contains class declarations with constructors, member function, and variables
- Source-file: Contains implementations

- Abstraction into interacting objects:
  - One Header & Source-file per object!
  - Gain understanding of program concept (i.e. objects and their interactions) by looking at header files only!

Code organization

- What about the following?
  - We have classes **`Date`**, **`Name`**, and **`Location`**
  - We have a class **`Birthday`** that includes
    - **`Date`** and **`Name`**
  - We have a class **`Meeting`** that includes
    - **`Date`** and **`Location`**
  - We have a class **`Calendar`** that includes
    - **`Birthday`** and **`Meeting`**

- Recursive resolving of #include will lead to double declaration of **`Date`**!

Code organization

- Include guards ensure unique declaration!

```
#ifndef DATE_HPP_
#define DATE_HPP_

class Date {
   …
};

#endif
```

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Compilation in C++

- instead of **`gcc`** use **`g++`**

- you can still use the same flags:
  - **`-Wall`** for all warnings
  - **`-c`** for denoting separate compilation
  - **`-o`** for naming an executable
  - **`-g`** for allowing use of a debugger
    - and any other flags you used with gcc

Compilation in C++

- Compiling multiple files:
  - `g++ main.cpp Class1.cpp Class2.cpp –o main`