Chapter 10 - Classes and Data Abstraction

Spring 2022

Objectives (1 of 2)

In this chapter, you will:

- Learn about classes
- Learn about `private`, `protected`, and `public` members of a class
- Explore how classes are implemented
- Become aware of accessor and mutator functions
- Examine constructors and destructors

Objectives (2 of 2)

- Learn about the abstract data type (ADT)
- Explore how classes are used to implement ADTs
- Become aware of the differences between a `struct` and a `class`
- Learn about information hiding
  - Explore how information hiding is implemented in C++
- Become aware of inline functions of a class
- Learn about the `static` members of a class

Classes (1 of 4)

- **Object-oriented design (OOD)**: a problem-solving methodology
- **Object**: combines data and the operations on that data in a single unit
- **Class**: a collection of a fixed number of components
- **Member**: a component of a class

Classes (2 of 4)

- The general syntax for defining a class:

```
class classIdentifier {
    classMemberList
};
```

- A class definition defines only a data type
  - No memory is allocated
  - Remember the semicolon (;) after the closing brace

Classes (3 of 4)

- A class member can be a variable or a function

- If a member of a class is a variable
  - It is declared like any other variable
  - You can initialize a variable when you declare it
- If a member of a class is a function
  - A function prototype declares that member
  - Function members can (directly) access any member of the class

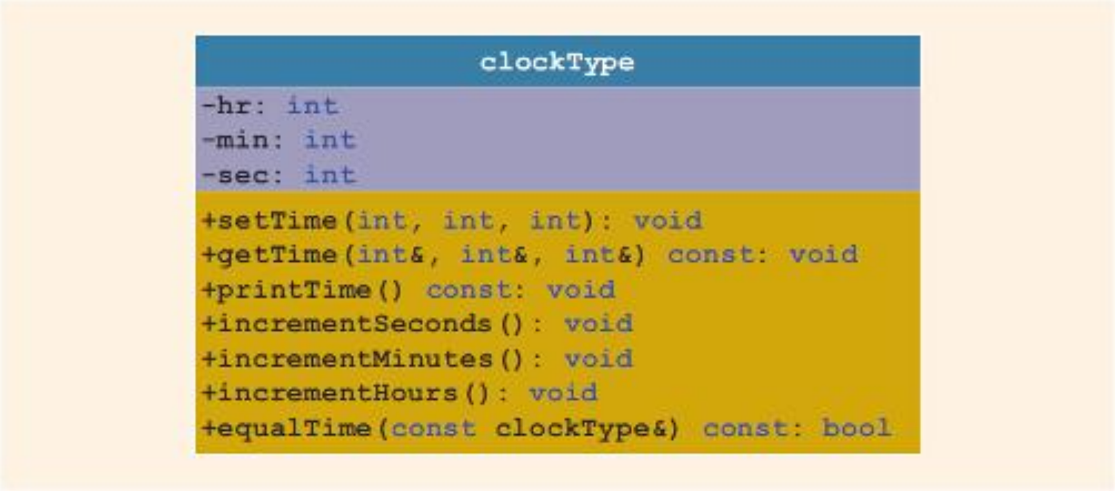
Classes (4 of 4)

- Three categories of class members:
- `private` (default)
  - Member cannot be accessed outside the class
- `public`
  - Member is accessible outside the class
- `protected`
  - Member is accessible within the class and all its subclasses (chapter 11).

Unified Modeling Language Class Diagrams (1 of 2)

- Unified Modeling Language (UML) notation: used to graphically describe a class and its members
  - + member is `public`
  - - member is `private`
  - # member is `protected`

Unified Modeling Language Class Diagrams (2 of 2)



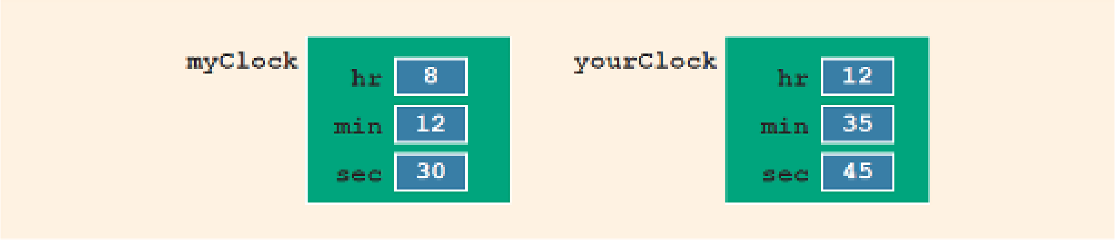
```
clockType
-hr: int
-min: int
-sec: int
+setTime(int, int, int): void
+getTime(int&, int&, int&) const: void
+printTime() const: void
+incrementSeconds(): void
+incrementMinutes(): void
+incrementHours(): void
+equalTime(const clockType&) const: bool
```

UML class diagram of the class `clockType`

Variable (Object) Declaration

- Once defined, you can declare variables of that class type
  - `clockType myClock;`
  - `clockType yourClock;`

- A class variable is called a **class object** or **class instance**



Objects `myClock` and `yourClock`

Accessing Class Members

- Once an object is declared, it can access the members of the class
- The general syntax for an object to access a member of a class:

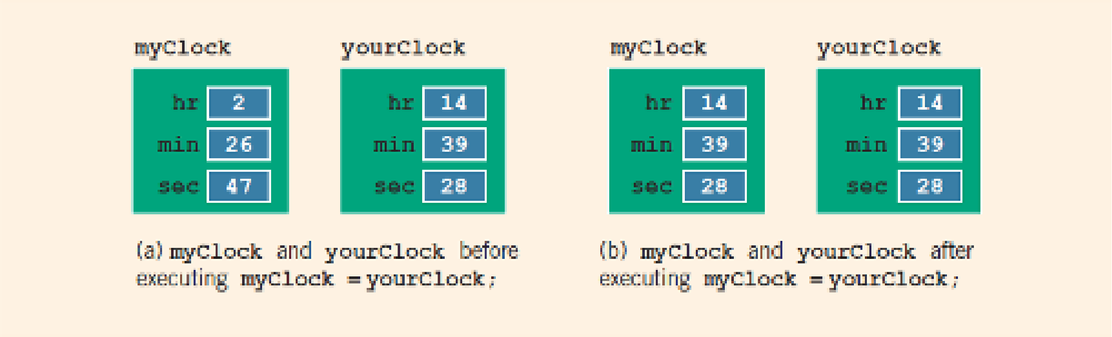
  `classObjectName.memberName`

  - The dot (`.`) is the **member access operator**
- If an object is declared in the definition of a member function of the class, it can access the public and private members

Built-in Operations on Classes

- Most of C++'s built-in operations do not apply to classes
  - Arithmetic operators cannot be used on class objects unless the operators are overloaded
  - Relational operators cannot be used to compare two class objects for equality
- Built-in operations that are valid for class objects:
  - Member access (`.`)
  - Assignment (`=`)

Assignment Operator and Classes



(a) myClock and yourClock before executing myClock = yourClock;

(b) myClock and yourClock after executing myClock = yourClock;

myClock and yourClock before and after executing the statement `myClock= yourClock;`

Class Scope (1 of 2)

- A `class` object can be automatic or static

    - Automatic: created when the declaration is reached and destroyed when the surrounding block is exited
    - Static: created when the declaration is reached and destroyed when the program terminates

Class Scope (2 of 2)

- A member of a `class` has the same scope as a member of a `struct`
    - A member of the `class` is local to the class
    - You access a class member outside the class by using the class object name and the member access operator (`.`)

Functions and Classes

- Objects can be passed as parameters to functions and returned as function values
- As parameters to functions:
    - Class objects can be passed by value or by reference
- If an object is passed by value:
    - Contents of data members of the actual parameter are copied into the corresponding data members of the formal parameter

Reference Parameters and Class Objects (Variables) (1 of 2)

- Passing by value might require a large amount of storage space and a considerable amount of computer time to copy the value of the actual parameter into the formal parameter
- If a variable is passed by reference:
    - The formal parameter receives only the address of the actual parameter

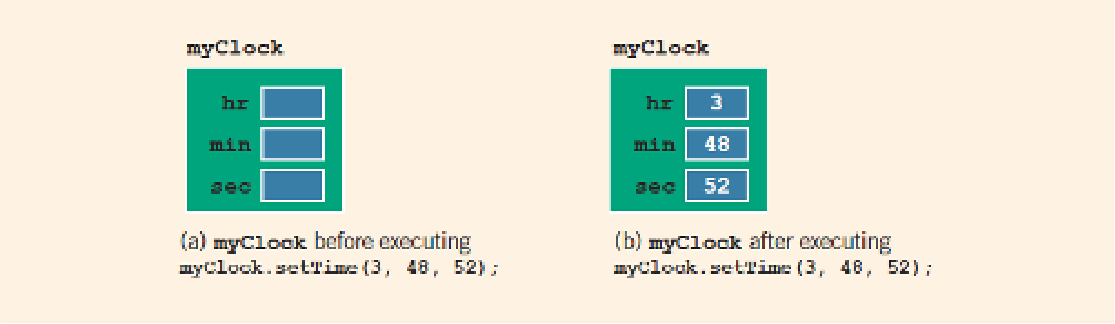
Reference Parameters and Class Objects (Variables) (2 of 2)

- Pass by reference is an efficient way to pass a variable as a parameter
    - Problem: when passing by reference, the actual parameter changes when the formal parameter changes
    - Solution: use `const` in the formal parameter declaration

Implementation of Member Functions (1 of 4)

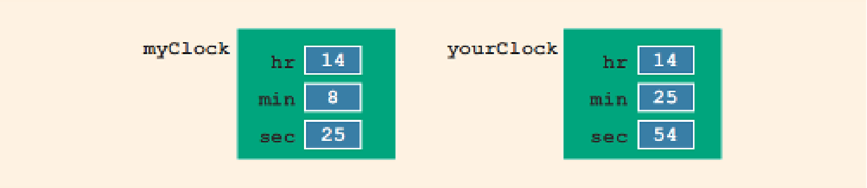
- Must write the code for functions defined as function prototypes
- Prototypes are left in the class to keep the class smaller and to hide the implementation
- To access identifiers local to the class, use the **scope resolution operator**, (`::`)

Implementation of Member Functions (2 of 4)

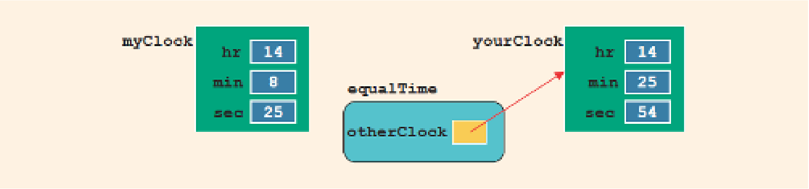

myClock
hr
min
sec
myClock
hr 3
min 48
sec 52
(a) myClock before executing
myClock.setTime(3, 48, 52);
(b) myClock after executing
myClock.setTime(3, 48, 52);

`myClock` before and after executing the statement `myClock.setTime(3, 48, 52);`

Implementation of Member Functions (3 of 4)



Objects `myClock` and `yourClock`



Object `myClock` and parameter `otherClock`

Implementation of Member Functions (4 of 4)

- Once a class is properly defined and implemented, it can be used in a program
  - A program that uses/manipulates objects of a class is called a **client** of that class
- When you declare objects of the `class clockType`, each object has its own copy of the member variables (`hr`, `min`, and `sec`)
  - These variables are called **instance variables** of the class
  - Every object has its own copy of the data

Accessor and Mutator Functions

- **Accessor function**: member function that only accesses the value(s) of member variable(s)
- **Mutator function**: member function that modifies the value(s) of member variable(s)
- Constant member function

  - Member function that cannot modify member variables of that class
  - Member function heading with `const` at the end

Order of public and private Members of a Class

- C++ has no fixed order in which to declare `public` and `private` members
- By default, all members of a class are `private`
- Use the member access specifier `public` to make a member available for public access

Constructors (1 of 2)

- Use constructors to guarantee that member variables of a class are initialized
- Two types of constructors
  - With parameters
  - Without parameters (**default constructor**)
- Other properties of constructors
  - Name of a constructor is the same as the name of the class
  - A constructor has no type

Constructors (2 of 2)

- A class can have more than one constructor
  - Each must have a different formal parameter list (signature)
- Constructors execute automatically when a class object enters its scope
  - They cannot be called like other functions
- Which constructor executes depends on the types of values passed to the class object when the class object is declared

Invoking a Constructor

- A constructor is automatically executed when a class variable is declared
- Because a class may have more than one constructor, you can invoke a specific constructor

Invoking the Default Constructor

- Syntax to invoke the default constructor is:

```
className classObjectName;
```

- Example. The statement

```
clockType yourClock;
```

declares `yourClock` to be an object of type `clockType` and the default constructor executes.

Invoking a Constructor with Parameters

- The syntax to invoke a constructor with a parameter is:

```
className classObjectName(arg1, arg2, ...);
```

- Number and type of arguments should match the formal parameters (in the order given) of one of the constructors
  - Otherwise, C++ uses type conversion and looks for the best match
  - Any ambiguity causes a compile-time error

Constructors and Default Parameters

- A constructor can have default parameters
  - Rules for declaring formal parameters are the same as for declaring default formal parameters in a function
  - Actual parameters are passed according to the same rules for functions
- A **default constructor** is a constructor with no parameters or with all default parameters

Classes and Constructors: A Precaution

- If a class has no constructor(s), C++ provides the default constructor
  - However, the object declared is potentially uninitialized if in-line initialization is not used.
- If a class includes constructor(s) with parameter(s), but not the default constructor
  - C++ does not provide the default constructor
  - Appropriate arguments must be included when the object is declared

In-line Initialization of Data Members and the Default Constructor

- C++14 standard allows member initialization in class declarations
  - Called in-line initialization of the data members
- When an object is declared without parameters, then the object is initialized with the in-line initialized values
  - If declared with parameters, then the default values are overridden by the constructor with the parameters

Arrays of Class Objects (Variables) and Constructors

- If you declare an array of class objects, the class should have the default constructor
  - The default constructor is typically used to initialize each (array) class object
  - As a general rule, classes should always have a default constructor.

Destructors

- Destructors are functions without any type
- A class can have only one destructor
  - The destructor has no parameters
- The name of a destructor is the tilde character (~) followed by the class name
  - Example: `~clockType();`
- The destructor automatically executes when the class object goes out of scope

  - The destructor should never be invoked directly.

Data Abstract, Classes, and Abstract Data Types

- **Abstraction**
  - Separating design details from usage
  - Separating the logical properties from the implementation details
- Abstraction also applicable to data
- **Abstract data type (ADT)**: a data type that separates the logical properties from the implementation details
- Three things associated with an ADT
  - **Type name**: the name of the ADT
  - **Domain**: the set of values belonging to the ADT
  - Set of **operations** on the data

A struct versus a class (1 of 2)

- By default, members of a `struct` are `public`
  - `private` specifier can be used in a `struct` to make a member private
- By default, the members of a class are `private`
  - classes and structs have the same capabilities

A struct versus a class (2 of 2)

- In C++, the definition of a struct was expanded to include member functions, constructors, and destructors
- If all member variables of a class are public and there are no member functions:
  - Use a struct

Information Hiding (1 of 3)

- **Information hiding** refers to hiding the details of the operations on the data
- The **interface** (or **header**) file contains the specification details
  - The header file has an extension **`.h`**
- The **implementation** file contains the definitions of the functions to implement the operations of an object
  - This file has an extension **`.cpp`**
- In the header file, include function prototypes and comments that briefly describe the functions
  - Specify preconditions and/or postconditions

Information Hiding (2 of 3)

- Implementation file must include the header file via the `include` statement
- In the `include` statement:
  - User-defined header files are enclosed in double quotes (`""`)
  - System-provided header files are enclosed between angular brackets (`<>`)

Information Hiding (3 of 3)

- **Precondition**: a statement specifying the condition(s) that must be true before the function is called
- **Postcondition**: a statement specifying what is true after the function call is completed

Inline Functions

- An **inline function definition** is a member function definition given completely in the definition of the class
- Saves the overhead of a function invocation
  - Very short definitions should be defined as inline functions
  - Code's physical size increases with each call.

static Members of a Class (1 of 2)

- Use the keyword `static` to declare a function or variable of a class as `static`
- A `public static` function or member of a class can be accessed using the class name and the scope resolution operator
- `static` member variables of a class exist even if no object of that class type exists

static Members of a Class (2 of 2)

- Multiple objects of a class each have their own copy of non-static member variables (e.g., instance variables)
- All objects of a class share any `static` members of the class

Quick Review (1 of 3)

- A `class` is a collection of a fixed number of components
- Components of a class are called the members of the class
  - Accessed by name
  - Classified into one of three categories: `private`, `protected`, and `public`
- In C++, class variables are called class objects or class instances or, simply, objects

Quick Review (2 of 3)

- The only built-in operations on classes are assignment and member selection
- Constructors guarantee that data members are initialized when an object is declared
  - A default constructor has no parameters
- The destructor automatically executes when a class object goes out of scope
  - A class can have only one destructor
  - The destructor has no parameters

Quick Review (3 of 3)

- An abstract data type (ADT) is a data type that separates the logical properties from the implementation details
- A `public static` member, function or data, of a class can be accessed using the class name and the scope resolution operator, ::

- `static` member variables of a class exist even when no object of the class type exists
- Instance variables are non-static data members

Questions