Chapter 9
Classes

Yu-Shuen Wang, CS, NCTU

9.3 `Time` Class

- We begin with an example that consists of class `Time`, which represents the time of day in 24-hour clock format, the class's member functions and a `main` function that creates and manipulates a `Time` object.
- Function `main` uses this object and its member functions to set and display the time in both 24-hour and 12-hour formats.

```
1  // Fig. 9.1: fig09_01.cpp
2  // Time class.
3  #include <iostream>
4  #include <iomanip>
5  using namespace std;
6
7  // Time class definition
8  class Time
9  {
10 public:
11    Time(); // constructor
12    void setTime( int, int, int ); // set hour, minute and second
13    void printUniversal(); // print time in universal-time format
14    void printStandard(); // print time in standard-time format
15 private:
16    int hour; // 0 - 23 (24-hour clock format)
17    int minute; // 0 - 59
18    int second; // 0 - 59
19 }; // end class Time
20
```

Fig. 9.1 | Time class definition. (Part 1 of 4.)

```
21  // Time constructor initializes each data member to zero.
22  // Ensures all Time objects start in a consistent state.
23  Time::Time()
24  {
25     hour = minute = second = 0;
26  } // end Time constructor
27
28  // set new Time value using universal time; ensure that
29  // the data remains consistent by setting invalid values to zero
30  void Time::setTime( int h, int m, int s )
31  {
32     hour = ( h >= 0 && h < 24 ) ? h : 0; // validate hour
33     minute = ( m >= 0 && m < 60 ) ? m : 0; // validate minute
34     second = ( s >= 0 && s < 60 ) ? s : 0; // validate second
35  } // end function setTime
36
37  // print Time in universal-time format (HH:MM:SS)
38  void Time::printUniversal()
39  {
40     cout << setfill( '0' ) << setw( 2 ) << hour << ":"
41        << setw( 2 ) << minute << ":" << setw( 2 ) << second;
42  } // end function printUniversal
43
```

Fig. 9.1 | Time class definition. (Part 2 of 4.)

```
44  // print Time in standard-time format (HH:MM:SS AM or PM)
45  void Time::printStandard()
46  {
47     cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 ) << ":"
48        << setfill( '0' ) << setw( 2 ) << minute << ":" << setw( 2 )
49        << second << ( hour < 12 ? " AM" : " PM" );
50  } // end function printStandard
51
52  int main()
53  {
54     Time t; // instantiate object t of class Time
55
56     // output Time object t's initial values
57     cout << "The initial universal time is ";
58     t.printUniversal(); // 00:00:00
59     cout << "\nThe initial standard time is ";
60     t.printStandard(); // 12:00:00 AM
61
62     t.setTime( 13, 27, 6 ); // change time
63
64     // output Time object t's new values
65     cout << "\n\nUniversal time after setTime is ";
66     t.printUniversal(); // 13:27:06
```

Fig. 9.1 | Time class definition. (Part 3 of 4.)

```
67      cout << "\nStandard time after setTime is ";
68      t.printStandard(); // 1:27:06 PM
69
70      t.setTime( 99, 99, 99 ); // attempt invalid settings
71
72      // output t's values after specifying invalid values
73      cout << "\n\nAfter attempting invalid settings:"
74         << "\nUniversal time: ";
75      t.printUniversal(); // 00:00:00
76      cout << "\nStandard time: ";
77      t.printStandard(); // 12:00:00 AM
78      cout << endl;
79   } // end main
```

```
The initial universal time is 00:00:00
The initial standard time is 12:00:00 AM

Universal time after setTime is 13:27:06
Standard time after setTime is 1:27:06 PM

After attempting invalid settings:
Universal time: 00:00:00
Standard time: 12:00:00 AM
```

Fig. 9.1 | `Time` class definition. (Part 4 of 4.)

9.3 `Time` Class (cont.)

- Line 10 contains the access-specifier label `public:`.
- The keyword `public` is an access specifier.
- The functions appear after access specifier `public:` to indicate that these functions are "available to the public"—that is, they can be called by other functions in the program (such as `main`), and by member functions of other classes (if there are any).
- Access specifiers are always followed by a colon (`:`).

9.3 Time Class (cont.)

- The public functions will be used by clients (i.e., portions of a program that are users) of the class to manipulate the class's data.
- These services allow the client code to interact with an object of the class.
- The member function with the same name as the class is called a constructor.
- This is a special member function that initializes the data members of a class object.

9.3 Time Class (cont.)

- A class's constructor is called when a program creates an object of that class.
- It's common to have several constructors for a class, enabling objects to be initialized several ways.
- Constructors cannot specify a return type; otherwise, a compilation error occurs.

9.3 `Time` Class (cont.)

- These declarations appear after the access-specifier label `private:`.
- Like `public`, keyword `private` is an access specifier.
- Variables or functions declared after access specifier `private` (and before the next access specifier) are accessible only to member functions of the class for which they're declared.

9.3 `Time` Class (cont.)

- `private` data members cannot be accessed by functions outside the class (such as `main`) or by member functions of other classes in the program.
- Normally, data members are listed in the `private` portion of a class and member functions are listed in the `public` portion.
- Using `public` data is uncommon and is considered poor software engineering.

Software Engineering Observation 9.1

Generally, data members should be declared `private` *and member functions should be declared* `public`*. It's appropriate to declare certain member functions* `private`*, if they're to be accessed only by other member functions of the class.*

Software Engineering Observation 9.2

Each element of a class should be `private` *unless it can be proven that the element needs to be* `public`*. This is another example of the principle of least privilege.*

9.3 Time Class (cont.)

- The data members of a class cannot be initialized where they're declared in the class body.
- It's strongly recommended that these data members be initialized by the class's constructor (as there's no default initialization for fundamental-type data members).

9.3 `Time` Class (cont.)

- Each member-function name in the function headers (lines 23, 30, 38 and 45) is preceded by the class name and `::`, which is known as the binary scope resolution operator.
- Without "`Time::`" preceding each function name, these functions would not be recognized by the compiler as member functions of class `Time`—the compiler would consider them "free" or "loose" functions, like `main`.

9.3 `Time` Class (cont.)

- Each class you create becomes a new type that can be used to create objects.
- Once class `Time` has been defined, it can be used as a type in object, array, pointer and reference declarations.
- When the object is instantiated (line 54), the `Time` constructor is called to initialize each `private` data member to `0`.

9.3 `Time` Class (cont.)

- Note that the data members `hour`, `minute` and `second` (lines 16–18) are preceded by the `private` member access specifier (line 15).
- Classes simplify programming because the client need only be concerned with the operations encapsulated or embedded in the object.
- Such operations are usually designed to be client oriented rather than implementation oriented.

9.3 Time Class (cont.)

- Clients need not be concerned with a class's implementation.
- Interfaces do change, but less frequently than implementations.
- Hiding the implementation eliminates the possibility of other program parts becoming dependent on the details of the class implementation.

9.3 Time Class (cont.)

- Classes do not have to be created "from scratch." They can include objects of other classes as members or they may be derived from other classes that provide attributes and behaviors the new classes can use.
- Such software reuse can greatly enhance productivity and simplify code maintenance.

Performance Tip 9.1

Objects contain only data, so objects are much smaller than if they also contained member functions. Applying operator `sizeof` *to a class name or to an object of that class will report only the size of the class's data members. The compiler creates one copy (only) of the member functions separate from all objects of the class. All objects of the class share this one copy. Each object, of course, needs its own copy of the class's data, because the data can vary among the objects. The function code is nonmodifiable and, hence, can be shared among all objects of one class.*

9.4 Class Scope and Accessing Class Members

- A class's data members and member functions (variables and functions declared in the class definition) belong to that class's scope.
- Within a class's scope, class members are immediately accessible by all of that class's member functions and can be referenced by name.

9.4 Class Scope and Accessing Class Members (cont.)

- Variables declared in a member function have local scope and are known only to that function.
- If a member function defines a variable with the same name as a variable with class scope, the class-scope variable is hidden by the block-scope variable in the local scope.
- Such a hidden variable can be accessed by preceding the variable name with the class name followed by the scope resolution operator (`::`).

9.4 Class Scope and Accessing Class Members (cont.)

- The dot member selection operator (.) is preceded by an object's name or with a reference to an object to access the object's members.
- The arrow member selection operator (->) is preceded by a pointer to an object to access the object's members.

```
1  // Fig. 9.2: fig09_02.cpp
2  // Demonstrating the class member access operators . and ->
3  #include <iostream>
4  using namespace std;
5
6  // class Count definition
7  class Count
8  {
9  public: // public data is dangerous
10    // sets the value of private data member x
11    void setX( int value )
12    {
13       x = value;
14    } // end function setX
15
16    // prints the value of private data member x
17    void print()
18    {
19       cout << x << endl;
20    } // end function print
21
```

Fig. 9.2 | Accessing an object's member functions through each type of object handle—the object's name, a reference to the object and a pointer to the object. (Part 1 of 3.)

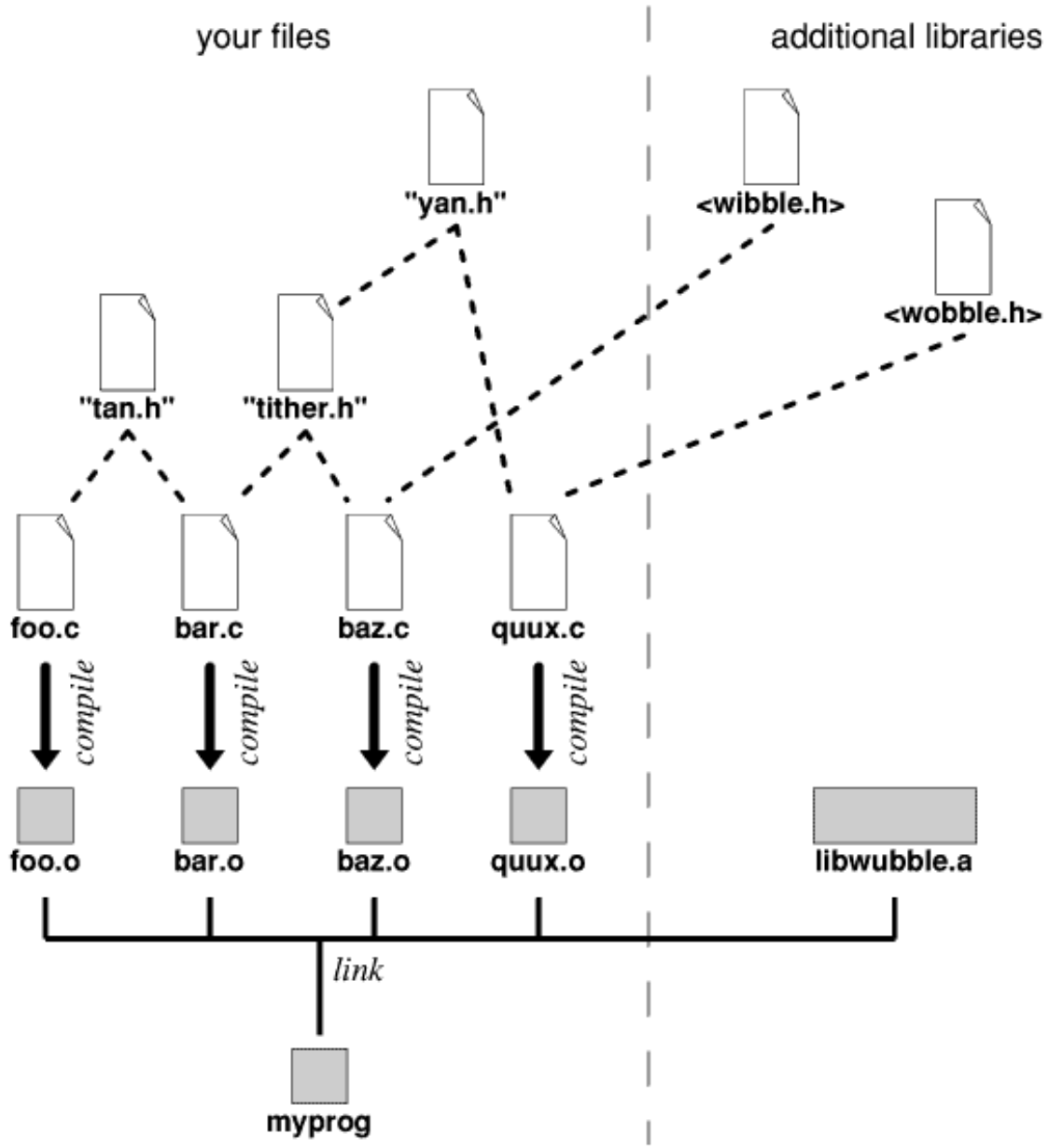
```
22  private:
23     int x;
24  }; // end class Count
25
26  int main()
27  {
28     Count counter; // create counter object
29     Count *counterPtr = &counter; // create pointer to counter
30     Count &counterRef = counter; // create reference to counter
31
32     cout << "Set x to 1 and print using the object's name: ";
33     counter.setX( 1 ); // set data member x to 1
34     counter.print(); // call member function print
35
36     cout << "Set x to 2 and print using a reference to an object: ";
37     counterRef.setX( 2 ); // set data member x to 2
38     counterRef.print(); // call member function print
39
40     cout << "Set x to 3 and print using a pointer to an object: ";
41     counterPtr->setX( 3 ); // set data member x to 3
42     counterPtr->print(); // call member function print
43  } // end main
```

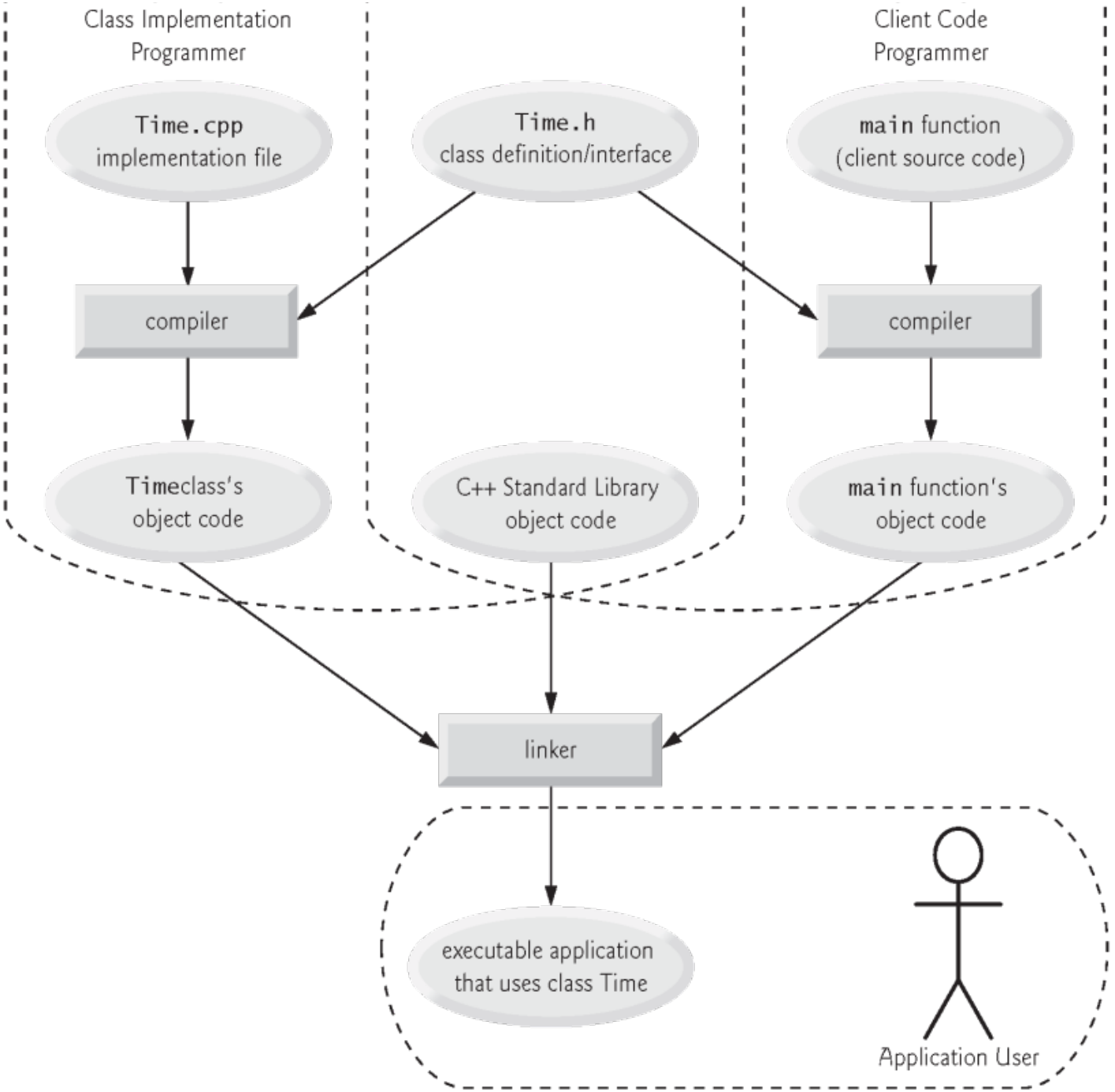
Fig. 9.2 | Accessing an object's member functions through each type of object handle—the object's name, a reference to the object and a pointer to the object. (Part 2 of 3.)

```
Set x to 1 and print using the object's name: 1
Set x to 2 and print using a reference to an object: 2
Set x to 3 and print using a pointer to an object: 3
```

Fig. 9.2 | Accessing an object's member functions through each type of object handle—the object's name, a reference to the object and a pointer to the object. (Part 3 of 3.)

Basic code compiling review




Class Implementation Programmer
Client Code Programmer
Time.cpp implementation file
Time.h class definition/interface
main function (client source code)
compiler
compiler
Timeclass's object code
C++ Standard Library object code
main function's object code
linker
executable application that uses class Time
Application User

9.4 Class Scope and Accessing Class Members (cont.)

- The member functions in Fig. 9.2 are defined completely in the body of class `Count`'s definition.
- In such cases, the compiler attempts to inline calls to the member function.
- Remember that the compiler reserves the right not to inline any function.

Performance Tip 9.2

Defining a member function inside the class definition inlines the member function (if the compiler chooses to do so). This can improve performance.

9.5 Placing a Class in a Separate File for Reusability

- One of the benefits of creating class definitions is that, when packaged properly, our classes can be reused by programmers—potentially worldwide.
- For example, we can reuse C++ Standard Library type `string` in any C++ program by including the header file `<string>`.

9.5 Placing a Class in a Separate File for Reusability (cont.)

- Programmers who wish to use our `Time` class cannot simply include the file from Fig. 9.1 in another program.
- Function `main` begins the execution of every program, and every program must have exactly one `main` function.
- If other programmers include the code from Fig. 9.1, they get extra baggage—our `main` function—and their programs will then have two `main` functions.

9.5 Placing a Class in a Separate File for Reusability (cont.)

- When building an object-oriented C++ program, it's customary to define reusable source code (such as a class) in a file that by convention has a `.h` filename extension—known as a header file.
- Programs use `#include` preprocessor directives to include header files and take advantage of reusable software components, such as type `string` provided in the C++ Standard Library and user-defined types like class `Time`.

Software Engineering Observation 9.5

Defining a small member function inside the class definition does not promote the best software engineering, because clients of the class will be able to see the implementation of the function, and the client code must be recompiled if the function definition changes.

header file

Software Engineering Observation 9.6

Only the simplest and most stable member functions (i.e., whose implementations are unlikely to change) should be defined in the class header.

9.6 `Time` Class: Separating Interface from Implementation

- We now show how to promote software reusability by separating a class definition from the client code (e.g., function `main`) that uses the class.
- We also introduce another fundamental principle of good software engineering—separating interface from implementation.

9.6 `Time` Class: Separating Interface from Implementation (cont.)

- Interfaces define and standardize the ways in which things such as people and systems interact with one another.
- The interface of a class describes what services a class's clients can use and how to request those services, but not how the class carries out the services.
- A class's `public` interface consists of the class's `public` member functions (also known as the class's `public` services).

9.6 `Time` Class: Separating Interface from Implementation (cont.)

- It's better software engineering to define member functions *outside* the class definition, so that their implementation details can be hidden from the client code.
  - This practice ensures that you do not write client code that depends on the class's implementation details.
  - If you were to do so, the client code would be more likely to "break" if the class's implementation changed.

```
1  // Fig. 9.3: Time.h
2  // Declaration of class Time.
3  // Member functions are defined in Time.cpp
4
5  // prevent multiple inclusions of header file
6  #ifndef TIME_H
7  #define TIME_H
8
9  // Time class definition
10 class Time
11 {
12 public:
13    Time(); // constructor
14    void setTime( int, int, int ); // set hour, minute and second
15    void printUniversal(); // print time in universal-time format
16    void printStandard(); // print time in standard-time format
17 private:
18    int hour; // 0 - 23 (24-hour clock format)
19    int minute; // 0 - 59
20    int second; // 0 - 59
21 }; // end class Time
22
23 #endif
```

Fig. 9.3 | Time class definition.

```
1  // Fig. 9.4: Time.cpp
2  // Member-function definitions for class Time.
3  #include <iostream>
4  #include <iomanip>
5  #include "Time.h" // include definition of class Time from Time.h
6  using namespace std;
7
8  // Time constructor initializes each data member to zero.
9  // Ensures all Time objects start in a consistent state.
10 Time::Time()
11 {
12    hour = minute = second = 0;
13 } // end Time constructor
14
15 // set new Time value using universal time; ensure that
16 // the data remains consistent by setting invalid values to zero
17 void Time::setTime( int h, int m, int s )
18 {
19    hour = ( h >= 0 && h < 24 ) ? h : 0; // validate hour
20    minute = ( m >= 0 && m < 60 ) ? m : 0; // validate minute
21    second = ( s >= 0 && s < 60 ) ? s : 0; // validate second
22 } // end function setTime
23
```

Fig. 9.4 | Time class member-function definitions. (Part 1 of 2.)

```
24  // print Time in universal-time format (HH:MM:SS)
25  void Time::printUniversal()
26  {
27     cout << setfill( '0' ) << setw( 2 ) << hour << ":"
28        << setw( 2 ) << minute << ":" << setw( 2 ) << second;
29  } // end function printUniversal
30
31  // print Time in standard-time format (HH:MM:SS AM or PM)
32  void Time::printStandard()
33  {
34     cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 ) << ":"
35        << setfill( '0' ) << setw( 2 ) << minute << ":" << setw( 2 )
36        << second << ( hour < 12 ? " AM" : " PM" );
37  } // end function printStandard
```

Fig. 9.4 | `Time` class member-function definitions. (Part 2 of 2.)

9.6 `Time` Class: Separating Interface from Implementation (cont.)

- In Fig. 9.3, the class definition is enclosed in the following preprocessor wrapper (lines 6, 7 and 23):

```
// prevent multiple inclusions of header file
#ifndef TIME_H
#define TIME_H
   ...
#endif
```

- When we build larger programs, other definitions and declarations will also be placed in header files.
- The preceding preprocessor wrapper prevents the code between `#ifndef` (which means “if not defined”) and `#endif` from being included if the name `TIME_H` has been defined.

9.6 `Time` Class: Separating Interface from Implementation (cont.)

- If the header has not been included previously in a file, the name `TIME_H` is defined by the `#define` directive and the header file statements are included.
- If the header has been included previously, `TIME_H` is defined already and the header file is not included again.
- Attempts to include a header file multiple times typically occur in large programs with many header files that may themselves include other header files.

Good Programming Practice 9.2

Use the name of the header file in upper case with the period replaced by an underscore in the `#ifndef` *and* `#define` *preprocessor directives of a header file.*

9.6 `Time` Class: Separating Interface from Implementation (cont.)

- Separating `Time`'s interface from its member-function implementation does not affect the way that this client code uses the class.
- It affects only how the program is compiled and linked, which we discuss in detail shortly.

9.6 `Time` Class: Separating Interface from Implementation (cont.)

- As in Fig. 9.4, line 5 of Fig. 9.5 includes the `Time.h` header file so that the compiler can ensure that `Time` objects are created and manipulated correctly in the client code.
- Before executing this program, the source-code files in Figs. 9.4 and 9.5 must both be compiled, then linked together—that is, the member-function calls in the client code need to be tied to the implementations of the class's member functions—a job performed by the linker.

```
1  // Fig. 9.5: fig09_05.cpp
2  // Program to test class Time.
3  // NOTE: This file must be compiled with Time.cpp.
4  #include <iostream>
5  #include "Time.h" // include definition of class Time from Time.h
6  using namespace std;
7
8  int main()
9  {
10    Time t; // instantiate object t of class Time
11
12    // output Time object t's initial values
13    cout << "The initial universal time is ";
14    t.printUniversal(); // 00:00:00
15    cout << "\nThe initial standard time is ";
16    t.printStandard(); // 12:00:00 AM
17
18    t.setTime( 13, 27, 6 ); // change time
19
20    // output Time object t's new values
21    cout << "\n\nUniversal time after setTime is ";
22    t.printUniversal(); // 13:27:06
23    cout << "\nStandard time after setTime is ";
24    t.printStandard(); // 1:27:06 PM
```

Fig. 9.5 | Program to test class `Time`. (Part 1 of 2.)

```
25
26      t.setTime( 99, 99, 99 ); // attempt invalid settings
27
28      // output t's values after specifying invalid values
29      cout << "\n\nAfter attempting invalid settings:"
30         << "\nUniversal time: ";
31      t.printUniversal(); // 00:00:00
32      cout << "\nStandard time: ";
33      t.printStandard(); // 12:00:00 AM
34      cout << endl;
35   } // end main
```

```
The initial universal time is 00:00:00
The initial standard time is 12:00:00 AM

Universal time after setTime is 13:27:06
Standard time after setTime is 1:27:06 PM

After attempting invalid settings:
Universal time: 00:00:00
Standard time: 12:00:00 AM
```

Fig. 9.5 | Program to test class `Time`. (Part 2 of 2.)

Software Engineering Observation 9.7

Clients of a class do not need access to the class's source code in order to use the class. The clients do, however, need to be able to link to the class's object code (i.e., the compiled version of the class). This encourages independent software vendors (ISVs) to provide class libraries for sale or license. The ISVs provide in their products only the header files and the object modules. No proprietary information is revealed—as would be the case if source code were provided. The C++ user community benefits by having more ISV-produced class libraries available.

Software Engineering Observation 9.8

Information important to the interface of a class should be included in the header file. Information that will be used only internally in the class and will not be needed by clients of the class should be included in the unpublished source file. This is yet another example of the principle of least privilege.

9.7 Access Functions and Utility Functions

- Access functions can read or display data.
- Another common use for access functions is to test the truth or falsity of conditions—such functions are often called predicate functions.
- Useful predicate functions for our `Time` class might be `isAM` and `isPM`.

9.7 Access Functions and Utility Functions (cont.)

- A utility function is not part of a class's `public` interface; rather, it's a `private` member function that supports the operation of the class's `public` member functions.
- Utility functions are not intended to be used by clients of a class.

```
1  // Fig. 9.7: SalesPerson.h
2  // SalesPerson class definition.
3  // Member functions defined in SalesPerson.cpp.
4  #ifndef SALESP_H
5  #define SALESP_H
6
7  class SalesPerson
8  {
9  public:
10    static const int monthsPerYear = 12; // months in one year
11    SalesPerson(); // constructor
12    void getSalesFromUser(); // input sales from keyboard
13    void setSales( int, double ); // set sales for a specific month
14    void printAnnualSales(); // summarize and print sales
15 private:
16    double totalAnnualSales(); // prototype for utility function
17    double sales[ monthsPerYear ]; // 12 monthly sales figures
18 }; // end class SalesPerson
19
20 #endif
```

Fig. 9.7 | SalesPerson class definition.

```
1  // Fig. 9.8: SalesPerson.cpp
2  // SalesPerson class member-function definitions.
3  #include <iostream>
4  #include <iomanip>
5  #include "SalesPerson.h" // include SalesPerson class definition
6  using namespace std;
7
8  // initialize elements of array sales to 0.0
9  SalesPerson::SalesPerson()
10 {
11    for ( int i = 0; i < monthsPerYear; i++ )
12       sales[ i ] = 0.0;
13 } // end SalesPerson constructor
14
```

Fig. 9.8 | `SalesPerson` class member-function definitions. (Part 1 of 3.)

```
15  // get 12 sales figures from the user at the keyboard
16  void SalesPerson::getSalesFromUser()
17  {
18     double salesFigure;
19
20     for ( int i = 1; i <= monthsPerYear; i++ )
21     {
22        cout << "Enter sales amount for month " << i << ": ";
23        cin >> salesFigure;
24        setSales( i, salesFigure );
25     } // end for
26  } // end function getSalesFromUser
27
28  // set one of the 12 monthly sales figures; function subtracts
29  // one from month value for proper subscript in sales array
30  void SalesPerson::setSales( int month, double amount )
31  {
32     // test for valid month and amount values
33     if ( month >= 1 && month <= monthsPerYear && amount > 0 )
34        sales[ month - 1 ] = amount; // adjust for subscripts 0-11
35     else // invalid month or amount value
36        cout << "Invalid month or sales figure" << endl;
37  } // end function setSales
```

Fig. 9.8 | `SalesPerson` class member-function definitions. (Part 2 of 3.)

```
38
39  // print total annual sales (with the help of utility function)
40  void SalesPerson::printAnnualSales()
41  {
42     cout << setprecision( 2 ) << fixed
43        << "\nThe total annual sales are: $"
44        << totalAnnualSales() << endl; // call utility function
45  } // end function printAnnualSales
46
47  // private utility function to total annual sales
48  double SalesPerson::totalAnnualSales()
49  {
50     double total = 0.0; // initialize total
51
52     for ( int i = 0; i < monthsPerYear; i++ ) // summarize sales results
53        total += sales[ i ]; // add month i sales to total
54
55     return total;
56  } // end function totalAnnualSales
```

Fig. 9.8 | `SalesPerson` class member-function definitions. (Part 3 of 3.)

```
1  // Fig. 9.9: fig09_09.cpp
2  // Utility function demonstration.
3  // Compile this program with SalesPerson.cpp
4
5  // include SalesPerson class definition from SalesPerson.h
6  #include "SalesPerson.h"
7
8  int main()
9  {
10    SalesPerson s; // create SalesPerson object s
11
12    s.getSalesFromUser(); // note simple sequential code; there are
13    s.printAnnualSales(); // no control statements in main
14 } // end main
```

Fig. 9.9 | Utility function demonstration. (Part 1 of 2.)

```
Enter sales amount for month 1: 5314.76
Enter sales amount for month 2: 4292.38
Enter sales amount for month 3: 4589.83
Enter sales amount for month 4: 5534.03
Enter sales amount for month 5: 4376.34
Enter sales amount for month 6: 5698.45
Enter sales amount for month 7: 4439.22
Enter sales amount for month 8: 5893.57
Enter sales amount for month 9: 4909.67
Enter sales amount for month 10: 5123.45
Enter sales amount for month 11: 4024.97
Enter sales amount for month 12: 5923.92

The total annual sales are: $60120.59
```

Fig. 9.9 | Utility function demonstration. (Part 2 of 2.)

```
1  // Fig. 9.10: Time.h
2  // Time class containing a constructor with default arguments.
3  // Member functions defined in Time.cpp.
4
5  // prevent multiple inclusions of header file
6  #ifndef TIME_H
7  #define TIME_H
8
9  // Time abstract data type definition
10 class Time
11 {
12 public:
13    Time( int = 0, int = 0, int = 0 ); // default constructor
14    void setTime( int, int, int ); // set hour, minute, second
15    void printUniversal(); // output time in universal-time format
16    void printStandard(); // output time in standard-time format
17 private:
18    int hour; // 0 - 23 (24-hour clock format)
19    int minute; // 0 - 59
20    int second; // 0 - 59
21 }; // end class Time
22
23 #endif
```

Fig. 9.10 | `Time` class containing a constructor with default arguments.

```
1  // Fig.9.11: Time.cpp
2  // Member-function definitions for class Time.
3  #include <iostream>
4  #include <iomanip>
5  #include "Time.h" // include definition of class Time from Time.h
6  using namespace std;
7
8  // Time constructor initializes each data member to zero;
9  // ensures that Time objects start in a consistent state
10 Time::Time( int hr, int min, int sec )
11 {
12    setTime( hr, min, sec ); // validate and set time
13 } // end Time constructor
14
15 // set new Time value using universal time; ensure that
16 // the data remains consistent by setting invalid values to zero
17 void Time::setTime( int h, int m, int s )
18 {
19    hour = ( h >= 0 && h < 24 ) ? h : 0; // validate hour
20    minute = ( m >= 0 && m < 60 ) ? m : 0; // validate minute
21    second = ( s >= 0 && s < 60 ) ? s : 0; // validate second
22 } // end function setTime
```

Fig. 9.11 | `Time` class member-function definitions including a constructor that takes arguments. (Part 1 of 2.)

```
23
24 // print Time in universal-time format (HH:MM:SS)
25 void Time::printUniversal()
26 {
27    cout << setfill( '0' ) << setw( 2 ) << hour << ":"
28       << setw( 2 ) << minute << ":" << setw( 2 ) << second;
29 } // end function printUniversal
30
31 // print Time in standard-time format (HH:MM:SS AM or PM)
32 void Time::printStandard()
33 {
34    cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 ) << ":"
35       << setfill( '0' ) << setw( 2 ) << minute << ":" << setw( 2 )
36       << second << ( hour < 12 ? " AM" : " PM" );
37 } // end function printStandard
```

Fig. 9.11 | `Time` class member-function definitions including a constructor that takes arguments. (Part 2 of 2.)

```
1  // Fig. 9.12: fig09_12.cpp
2  // Demonstrating a default constructor for class Time.
3  #include <iostream>
4  #include "Time.h" // include definition of class Time from Time.h
5  using namespace std;
6
7  int main()
8  {
9     Time t1; // all arguments defaulted
10    Time t2( 2 ); // hour specified; minute and second defaulted
11    Time t3( 21, 34 ); // hour and minute specified; second defaulted
12    Time t4( 12, 25, 42 ); // hour, minute and second specified
13    Time t5( 27, 74, 99 ); // all bad values specified
14
15    cout << "Constructed with:\n\nt1: all arguments defaulted\n  ";
16    t1.printUniversal(); // 00:00:00
17    cout << "\n  ";
18    t1.printStandard(); // 12:00:00 AM
19
20    cout << "\n\nt2: hour specified; minute and second defaulted\n  ";
21    t2.printUniversal(); // 02:00:00
22    cout << "\n  ";
23    t2.printStandard(); // 2:00:00 AM
```

Fig. 9.12 | Constructor with default arguments. (Part 1 of 3.)

```
24
25      cout << "\n\nt3: hour and minute specified; second defaulted\n  ";
26      t3.printUniversal(); // 21:34:00
27      cout << "\n  ";
28      t3.printStandard(); // 9:34:00 PM
29
30      cout << "\n\nt4: hour, minute and second specified\n  ";
31      t4.printUniversal(); // 12:25:42
32      cout << "\n  ";
33      t4.printStandard(); // 12:25:42 PM
34
35      cout << "\n\nt5: all invalid values specified\n  ";
36      t5.printUniversal(); // 00:00:00
37      cout << "\n  ";
38      t5.printStandard(); // 12:00:00 AM
39      cout << endl;
40  } // end main
```

Fig. 9.12 | Constructor with default arguments. (Part 2 of 3.)

```
Constructed with:

t1: all arguments defaulted
  00:00:00
  12:00:00 AM

t2: hour specified; minute and second defaulted
  02:00:00
  2:00:00 AM

t3: hour and minute specified; second defaulted
  21:34:00
  9:34:00 PM

t4: hour, minute and second specified
  12:25:42
  12:25:42 PM

t5: all invalid values specified
  00:00:00
  12:00:00 AM
```

Fig. 9.12 | Constructor with default arguments. (Part 3 of 3.)

9.8 Time Class: Constructors with Default Arguments (cont.)

- A class gets a default constructor in one of two ways:
  - The compiler implicitly creates a default constructor in a class that does not define a constructor.
  - You explicitly define a constructor that takes no arguments.

- If you define a constructor with arguments, C++ will not implicitly create a default constructor for that class.

Software Engineering Observation 9.11

Data members can be initialized in a constructor, or their values may be set *later after the object is created. However, it's a good software engineering practice to ensure that an object is fully initialized before the client code invokes the object's member functions. You should not rely on the client code to ensure that an object gets initialized properly.*

9.9 Destructors

- A destructor is another type of special member function.
- The name of the destructor for a class is the tilde character (~) followed by the class name.
- A class's destructor is called implicitly when an object is destroyed.
- This occurs, for example, as an automatic object is destroyed when program execution leaves the scope in which that object was instantiated.

9.9 Destructors (cont.)

- The destructor itself does not actually release the object's memory
- A destructor receives no parameters and returns no value.
- A destructor may not specify a return type—not even `void`.
- A class have only one destructor—destructor overloading is not allowed.
- A destructor must be `public`.
- *Every class has a destructor.*
- If you do not explicitly provide a destructor, the compiler implicitly creates an "empty" destructor.

Common Programming Error 9.4

It's a syntax error to attempt to pass arguments to a destructor, to specify a return type for a destructor (even `void` *cannot be specified), to return values from a destructor or to overload a destructor.*

9.10 When Constructors and Destructors Are Called

- Constructors and destructors are called implicitly by the compiler.
- For objects defined in global scope:
  - Constructors are called before any other function (including `main`) in that file begins execution (the order of execution of global object constructors between files is not guaranteed).
  - The corresponding destructors are called when `main` terminates.

9.10 When Constructors and Destructors Are Called (cont.)

- For automatic local objects:
  - The constructor is called when execution reaches the point where that object is defined.
  - The corresponding destructor is called when execution leaves the object's scope (i.e., the block in which that object is defined has finished executing).
  - Destructors are not called for automatic objects if the program terminates with a call to function `exit` or function `abort`.

9.10 When Constructors and Destructors Are Called (cont.)

- For `static` local objects:
  - The constructor is called only once, when execution first reaches the point where the object is defined
  - The corresponding destructor is called when `main` terminates or the program calls function `exit`.
  - Global and `static` objects are destroyed in the reverse order of their creation.
  - Destructors are not called for `static` objects if the program terminates with a call to function `abort`.

9.10 When Constructors and Destructors Are Called (cont.)

- Function `exit` forces a program to terminate immediately and *does not* execute the destructors of automatic objects.
- Function `abort` performs similarly to function `exit` but forces the program to terminate immediately, without allowing the destructors of any objects to be called.

```
1  // Fig. 9.13: CreateAndDestroy.h
2  // CreateAndDestroy class definition.
3  // Member functions defined in CreateAndDestroy.cpp.
4  #include <string>
5  using namespace std;
6
7  #ifndef CREATE_H
8  #define CREATE_H
9
10 class CreateAndDestroy
11 {
12 public:
13    CreateAndDestroy( int, string ); // constructor
14    ~CreateAndDestroy(); // destructor
15 private:
16    int objectID; // ID number for object
17    string message; // message describing object
18 }; // end class CreateAndDestroy
19
20 #endif
```

Fig. 9.13 | CreateAndDestroy class definition.

```
1  // Fig. 9.14: CreateAndDestroy.cpp
2  // CreateAndDestroy class member-function definitions.
3  #include <iostream>
4  #include "CreateAndDestroy.h"// include CreateAndDestroy class definition
5  using namespace std;
6
7  // constructor
8  CreateAndDestroy::CreateAndDestroy( int ID, string messageString )
9  {
10    objectID = ID; // set object's ID number
11    message = messageString; // set object's descriptive message
12
13    cout << "Object " << objectID << "   constructor runs   "
14       << message << endl;
15 } // end CreateAndDestroy constructor
16
17 // destructor
18 CreateAndDestroy::~CreateAndDestroy()
19 {
20    // output newline for certain objects; helps readability
21    cout << ( objectID == 1 || objectID == 6 ? "\n" : "" );
22
23    cout << "Object " << objectID << "   destructor runs    "
24       << message << endl;
25 } // end ~CreateAndDestroy destructor
```

Fig. 9.14 | `CreateAndDestroy` class member-function definitions.

```
1  // Fig. 9.15: fig09_15.cpp
2  // Demonstrating the order in which constructors and
3  // destructors are called.
4  #include <iostream>
5  #include "CreateAndDestroy.h" // include CreateAndDestroy class definition
6  using namespace std;
7
8  void create( void ); // prototype
9
10 CreateAndDestroy first( 1, "(global before main)" ); // global object
11
12 int main()
13 {
14    cout << "\nMAIN FUNCTION: EXECUTION BEGINS" << endl;
15    CreateAndDestroy second( 2, "(local automatic in main)" );
16    static CreateAndDestroy third( 3, "(local static in main)" );
17
18    create(); // call function to create objects
19
20    cout << "\nMAIN FUNCTION: EXECUTION RESUMES" << endl;
21    CreateAndDestroy fourth( 4, "(local automatic in main)" );
22    cout << "\nMAIN FUNCTION: EXECUTION ENDS" << endl;
23 } // end main
```

Fig. 9.15 | Order in which constructors and destructors are called. (Part 1 of 3.)

```
24
25  // function to create objects
26  void create( void )
27  {
28     cout << "\nCREATE FUNCTION: EXECUTION BEGINS" << endl;
29     CreateAndDestroy fifth( 5, "(local automatic in create)" );
30     static CreateAndDestroy sixth( 6, "(local static in create)" );
31     CreateAndDestroy seventh( 7, "(local automatic in create)" );
32     cout << "\nCREATE FUNCTION: EXECUTION ENDS" << endl;
33  } // end function create
```

Fig. 9.15 | Order in which constructors and destructors are called. (Part 2 of 3.)

```
Object 1   constructor runs   (global before main)

MAIN FUNCTION: EXECUTION BEGINS
Object 2   constructor runs   (local automatic in main)
Object 3   constructor runs   (local static in main)

CREATE FUNCTION: EXECUTION BEGINS
Object 5   constructor runs   (local automatic in create)
Object 6   constructor runs   (local static in create)
Object 7   constructor runs   (local automatic in create)

CREATE FUNCTION: EXECUTION ENDS
Object 7   destructor runs    (local automatic in create)
Object 5   destructor runs    (local automatic in create)

MAIN FUNCTION: EXECUTION RESUMES
Object 4   constructor runs   (local automatic in main)

MAIN FUNCTION: EXECUTION ENDS
Object 4   destructor runs    (local automatic in main)
Object 2   destructor runs    (local automatic in main)

Object 6   destructor runs    (local static in create)
Object 3   destructor runs    (local static in main)

Object 1   destructor runs    (global before main)
```

Fig. 9.15 | Order in which constructors and destructors are called. (Part 3 of 3.)

```
1  // Fig. 9.16: Time.h
2  // Time class containing a constructor with default arguments.
3  // Member functions defined in Time.cpp.
4
5  // prevent multiple inclusions of header file
6  #ifndef TIME_H
7  #define TIME_H
8
9  // Time abstract data type definition
10 class Time
11 {
12 public:
13    Time( int = 0, int = 0, int = 0 ); // default constructor
14
15    // set functions
16    void setTime( int, int, int ); // set hour, minute, second
17    void setHour( int ); // set hour (after validation)
18    void setMinute( int ); // set minute (after validation)
19    void setSecond( int ); // set second (after validation)
20
```

Fig. 9.16 | Time class containing a constructor with default arguments. (Part 1 of 2.)

```
21      // get functions
22      int getHour(); // return hour
23      int getMinute(); // return minute
24      int getSecond(); // return second
25
26      void printUniversal(); // output time in universal-time format
27      void printStandard(); // output time in standard-time format
28   private:
29      int hour; // 0 - 23 (24-hour clock format)
30      int minute; // 0 - 59
31      int second; // 0 - 59
32   }; // end class Time
33
34   #endif
```

Fig. 9.16 | `Time` class containing a constructor with default arguments. (Part 2 of 2.)

```
1  // Fig. 9.17: Time.cpp
2  // Member-function definitions for class Time.
3  #include <iostream>
4  #include <iomanip>
5  #include "Time.h" // include definition of class Time from Time.h
6  using namespace std;
7
8  // Time constructor initializes each data member to zero;
9  // ensures that Time objects start in a consistent state
10 Time::Time( int hr, int min, int sec )
11 {
12    setTime( hr, min, sec ); // validate and set time
13 } // end Time constructor
14
15 // set new Time value using universal time; ensure that
16 // the data remains consistent by setting invalid values to zero
17 void Time::setTime( int h, int m, int s )
18 {
19    setHour( h ); // set private field hour
20    setMinute( m ); // set private field minute
21    setSecond( s ); // set private field second
22 } // end function setTime
```

Fig. 9.17 | `Time` class member-function definitions including a constructor that takes arguments. (Part 1 of 4.)

```
23
24    // set hour value
25    void Time::setHour( int h )
26    {
27       hour = ( h >= 0 && h < 24 ) ? h : 0; // validate hour
28    } // end function setHour
29
30    // set minute value
31    void Time::setMinute( int m )
32    {
33       minute = ( m >= 0 && m < 60 ) ? m : 0; // validate minute
34    } // end function setMinute
35
36    // set second value
37    void Time::setSecond( int s )
38    {
39       second = ( s >= 0 && s < 60 ) ? s : 0; // validate second
40    } // end function setSecond
41
```

Fig. 9.17 | `Time` class member-function definitions including a constructor that takes arguments. (Part 2 of 4.)

```
42   // return hour value
43   int Time::getHour()
44   {
45      return hour;
46   } // end function getHour
47
48   // return minute value
49   int Time::getMinute()
50   {
51      return minute;
52   } // end function getMinute
53
54   // return second value
55   int Time::getSecond()
56   {
57      return second;
58   } // end function getSecond
59
```

Fig. 9.17 | `Time` class member-function definitions including a constructor that takes arguments. (Part 3 of 4.)

```
60  // print Time in universal-time format (HH:MM:SS)
61  void Time::printUniversal()
62  {
63     cout << setfill( '0' ) << setw( 2 ) << getHour() << ":"
64        << setw( 2 ) << getMinute() << ":" << setw( 2 ) << getSecond();
65  } // end function printUniversal
66
67  // print Time in standard-time format (HH:MM:SS AM or PM)
68  void Time::printStandard()
69  {
70     cout << ( ( getHour() == 0 || getHour() == 12 ) ? 12 : getHour() % 12 )
71        << ":" << setfill( '0' ) << setw( 2 ) << getMinute()
72        << ":" << setw( 2 ) << getSecond() << ( hour < 12 ? " AM" : " PM" );
73  } // end function printStandard
```

Fig. 9.17 | `Time` class member-function definitions including a constructor that takes arguments. (Part 4 of 4.)

```
1  // Fig. 9.18: fig09_18.cpp
2  // Demonstrating the Time class set and get functions
3  #include <iostream>
4  #include "time.h"
5  using namespace std;
6
7  void incrementMinutes( Time &, const int ); // prototype
8
9  int main()
10 {
11    Time t; // create Time object
12
13    // set time using individual set functions
14    t.setHour( 17 );  // set hour to valid value
15    t.setMinute( 34 ); // set minute to valid value
16    t.setSecond( 25 ); // set second to valid value
17
18    // use get functions to obtain hour, minute and second
19    cout << "Result of setting all valid values:\n"
20         << "  Hour: " << t.getHour()
21         << "  Minute: " << t.getMinute()
22         << "  Second: " << t.getSecond();
```

Fig. 9.18 | *Set* and *get* functions manipulating an object's `private` data. (Part 1 of 4.)

```
23
24      // set time using individual set functions
25      t.setHour( 234 ); // invalid hour set to 0
26      t.setMinute( 43 ); // set minute to valid value
27      t.setSecond( 6373 ); // invalid second set to 0
28
29      // display hour, minute and second after setting
30      // invalid hour and second values
31      cout << "\n\nResult of attempting to set invalid hour and"
32           << " second:\n  Hour: " << t.getHour()
33           << "  Minute: " << t.getMinute()
34           << "  Second: " << t.getSecond() << "\n\n";
35
36      t.setTime( 11, 58, 0 ); // set time
37      incrementMinutes( t, 3 ); // increment t's minute by 3
38  } // end main
39
```

Fig. 9.18 | *Set* and *get* functions manipulating an object's `private` data. (Part 2 of 4.)

```
40  // add specified number of minutes to a Time object
41  void incrementMinutes( Time &tt, const int count )
42  {
43     cout << "Incrementing minute " << count
44          << " times:\nStart time: ";
45     tt.printStandard();
46
47     for ( int i = 0; i < count; i++ ) {
48        tt.setMinute( ( tt.getMinute() + 1 ) % 60 );
49
50        if ( tt.getMinute() == 0 )
51           tt.setHour( ( tt.getHour() + 1 ) % 24);
52
53        cout << "\nminute + 1: ";
54        tt.printStandard();
55     } // end for
56
57     cout << endl;
58  } // end function incrementMinutes
```

Fig. 9.18 | *Set* and *get* functions manipulating an object's `private` data. (Part 3 of 4.)

```
Result of setting all valid values:
  Hour: 17  Minute: 34  Second: 25

Result of attempting to set invalid hour and second:
  Hour: 0  Minute: 43  Second: 0

Incrementing minute 3 times:
Start time: 11:58:00 AM
minute + 1: 11:59:00 AM
minute + 1: 12:00:00 PM
minute + 1: 12:01:00 PM
```

Fig. 9.18 | *Set* and *get* functions manipulating an object's `private` data. (Part 4 of 4.)

9.11 `Time` Class: Using *Set* and *Get* Functions (cont.)

- A class's `private` data members can be manipulated only by member functions of that class (and by "friends" of the class, as we'll see in Chapter 10).
- So a client of an object calls the class's `public` member functions to request the class's services for particular objects of the class.
- Classes often provide `public` member functions to allow clients of the class to ***set*** (i.e., assign values to) or ***get*** (i.e., obtain the values of) `private` data members.

9.11 `Time` Class: Using *Set and Get Functions (cont.)*

- Declaring data members with access specifier `private` enforces data hiding.
- Providing `public` *set* and *get* functions allows clients of a class to access the hidden data, but only indirectly.
- The client knows that it's attempting to modify or obtain an object's data, but the client does not know how the object performs these operations.
- The *set* and *get* functions allow a client to interact with an object, but the object's `private` data remains safely encapsulated (i.e., hidden) in the object itself.

Software Engineering Observation 9.12

If a member function of a class already provides all or part of the functionality required by a constructor (or other member function) of the class, call that member function from the constructor (or other member function). This simplifies the maintenance of the code and reduces the likelihood of an error if the implementation of the code is modified. As a general rule: Avoid repeating code.

Software Engineering Observation 9.14

Provide set *or* get *functions for each* `private` *data item only when appropriate. Services useful to the client should typically be provided in the class's* `public` *interface.*

9.12 `Time` Class: A Subtle Trap—Returning a Reference to a `private` Data Member

- A reference to an object is an alias for the name of the object and, hence, may be used on the left side of an assignment statement.
- One way to use this capability (unfortunately!) is to have a `public` member function of a class return a reference to a `private` data member of that class.

```
1  // Fig. 9.19: Time.h
2  // Time class declaration.
3  // Member functions defined in Time.cpp
4
5  // prevent multiple inclusions of header file
6  #ifndef TIME_H
7  #define TIME_H
8
9  class Time
10 {
11 public:
12    Time( int = 0, int = 0, int = 0 );
13    void setTime( int, int, int );
14    int getHour();
15    int &badSetHour( int ); // DANGEROUS reference return
16 private:
17    int hour;
18    int minute;
19    int second;
20 }; // end class Time
21
22 #endif
```

Fig. 9.19 | `Time` class declaration.

```
1  // Fig. 9.20: Time.cpp
2  // Time class member-function definitions.
3  #include "Time.h" // include definition of class Time
4
5  // constructor function to initialize private data; calls member function
6  // setTime to set variables; default values are 0 (see class definition)
7  Time::Time( int hr, int min, int sec )
8  {
9     setTime( hr, min, sec );
10 } // end Time constructor
11
12 // set values of hour, minute and second
13 void Time::setTime( int h, int m, int s )
14 {
15    hour = ( h >= 0 && h < 24 ) ? h : 0; // validate hour
16    minute = ( m >= 0 && m < 60 ) ? m : 0; // validate minute
17    second = ( s >= 0 && s < 60 ) ? s : 0; // validate second
18 } // end function setTime
19
20 // return hour value
21 int Time::getHour()
22 {
23    return hour;
24 } // end function getHour
```

Fig. 9.20 | `Time` class member-function definitions. (Part 1 of 2.)

```
25
26   // POOR PRACTICE: Returning a reference to a private data member.
27   int &Time::badSetHour( int hh )
28   {
29      hour = ( hh >= 0 && hh < 24 ) ? hh : 0;
30      return hour; // DANGEROUS reference return
31   } // end function badSetHour
```

Fig. 9.20 | `Time` class member-function definitions. (Part 2 of 2.)

```
1  // Fig. 9.21: fig09_21.cpp
2  // Demonstrating a public member function that
3  // returns a reference to a private data member.
4  #include <iostream>
5  #include "Time.h" // include definition of class Time
6  using namespace std;
7
8  int main()
9  {
10    Time t; // create Time object
11
12    // initialize hourRef with the reference returned by badSetHour
13    int &hourRef = t.badSetHour( 20 ); // 20 is a valid hour
14
15    cout << "Valid hour before modification: " << hourRef;
16    hourRef = 30; // use hourRef to set invalid value in Time object t
17    cout << "\nInvalid hour after modification: " << t.getHour();
18
19    // Dangerous: Function call that returns
20    // a reference can be used as an lvalue!
21    t.badSetHour( 12 ) = 74; // assign another invalid value to hour
22
```

Fig. 9.21 | Returning a reference to a `private` data member. (Part 1 of 2.)

```
23      cout << "\n\n**********************************************\n"
24         << "POOR PROGRAMMING PRACTICE!!!!!!!\n"
25         << "t.badSetHour( 12 ) as an lvalue, invalid hour: "
26         << t.getHour()
27         << "\n**********************************************" << endl;
28   } // end main
```

```
Valid hour before modification: 20
Invalid hour after modification: 30

**********************************************
POOR PROGRAMMING PRACTICE!!!!!!!
t.badSetHour( 12 ) as an lvalue, invalid hour: 74
**********************************************
```

Fig. 9.21 | Returning a reference to a `private` data member. (Part 2 of 2.)

Error-Prevention Tip 9.6

Returning a reference or a pointer to a `private` *data member breaks the encapsulation of the class and makes the client code dependent on the representation of the class's data; this is a dangerous practice that should be avoided.*

9.13 Default Memberwise Assignment

- The assignment operator (=) can be used to assign an object to another object of the same type.
- By default, such assignment is performed by memberwise assignment
- Line 18 of Fig. 9.24 uses default memberwise assignment to assign the data members of `Date` object `date1` to the corresponding data members of `Date` object `date2`.

```
1  // Fig. 9.19: Date.h
2  // Date class declaration.  Member functions are defined in Date.cpp.
3
4  // prevent multiple inclusions of header file
5  #ifndef DATE_H
6  #define DATE_H
7
8  // class Date definition
9  class Date
10 {
11 public:
12    Date( int = 1, int = 1, int = 2000 ); // default constructor
13    void print();
14 private:
15    int month;
16    int day;
17    int year;
18 }; // end class Date
19
20 #endif
```

Fig. 9.22 | `Date` class declaration.

```
1  // Fig. 9.20: Date.cpp
2  // Date class member-function definitions.
3  #include <iostream>
4  #include "Date.h" // include definition of class Date from Date.h
5  using namespace std;
6
7  // Date constructor (should do range checking)
8  Date::Date( int m, int d, int y )
9  {
10    month = m;
11    day = d;
12    year = y;
13 } // end constructor Date
14
15 // print Date in the format mm/dd/yyyy
16 void Date::print()
17 {
18    cout << month << '/' << day << '/' << year;
19 } // end function print
```

Fig. 9.23 | `Date` class member-function definitions.

```
1  // Fig. 9.21: fig09_21.cpp
2  // Demonstrating that class objects can be assigned
3  // to each other using default memberwise assignment.
4  #include <iostream>
5  #include "Date.h" // include definition of class Date from Date.h
6  using namespace std;
7
8  int main()
9  {
10    Date date1( 7, 4, 2004 );
11    Date date2; // date2 defaults to 1/1/2000
12
13    cout << "date1 = ";
14    date1.print();
15    cout << "\ndate2 = ";
16    date2.print();
17
18    date2 = date1; // default memberwise assignment
19
20    cout << "\n\nAfter default memberwise assignment, date2 = ";
21    date2.print();
22    cout << endl;
23 } // end main
```

Fig. 9.24 | Default memberwise assignment. (Part 1 of 2.)

```
date1 = 7/4/2004
date2 = 1/1/2000

After default memberwise assignment, date2 = 7/4/2004
```

Fig. 9.24 | Default memberwise assignment. (Part 2 of 2.)

9.13 Default Memberwise Assignment (cont.)

- Objects may be passed as function arguments and may be returned from functions.
- Such passing and returning is performed using pass-by-value by default—a copy of the object is passed or returned.
- For each class, the compiler provides a default copy constructor that copies each member of the original object into the corresponding member of the new object.
- Copy constructors can cause serious problems when used with a class whose data members contain pointers to dynamically allocated memory.

Performance Tip 9.3

Passing an object by value is good from a security standpoint, because the called function has no access to the original object in the caller, but pass-by-value can degrade performance when making a copy of a large object. An object can be passed by reference by passing either a pointer or a reference to the object. Pass-by-reference offers good performance but is weaker from a security standpoint, because the called function is given access to the original object. Pass-by-`const`*-reference is a safe, good-performing alternative (this can be implemented with a* `const` *reference parameter or with a pointer-to-*`const`*-data parameter).*