Chapter 7

Constructors and Other Tools

Learning Objectives

- Constructors
  - Definitions
  - Calling
- More Tools
  - const parameter modifier
  - Inline functions
  - Static member data
- Vectors
  - Introduction to vector class

Constructors

- Initialization of objects
  - Initialize some or all member variables
  - Other actions possible as well
- A special kind of member function
  - Automatically called when object declared
- Very useful tool
  - Key principle of OOP

Constructor Definitions

- Constructors defined like any member function
  - Except:
    1. Must have same name as class
    2. Cannot return a value; not even void!

Constructor Definition Example

- Class definition with constructor:
  - class DayOfYear
    {
    public:
        DayOfYear(int monthValue, int dayValue);
                //Constructor initializes month and day
        void input();
        void output();
        …
    private:
        int month;
        int day;
    }

Constructor Notes

- Notice name of constructor: DayOfYear
  - Same name as class itself!
- Constructor declaration has no return-type
  - Not even void!
- Constructor in public section
  - It's called when objects are declared
  - If private, could never declare objects!

Calling Constructors

- Declare objects:

  DayOfYear date1(7, 4),
  date2(5, 5);

- Objects are created here
  - Constructor is called
  - Values in parens passed as arguments to constructor
  - Member variables month, day initialized:
    date1.month → 7 date2.month → 5
    date1.dat → 4 date2.day → 5

Constructor Equivalency

- Consider:
  - DayOfYear date1, date2
    date1.DayOfYear(7, 4); // ILLEGAL!
    date2.DayOfYear(5, 5); // ILLEGAL!
- Seemingly OK…
  - CANNOT call constructors like other member functions!

Constructor Code

- Constructor definition is like all other member functions:

```
DayOfYear::DayOfYear(int monthValue, int dayValue)
{
        month = monthValue;
        day = dayValue;
}
```

- Note same name around ::
  - Clearly identifies a constructor
- Note no return type
  - Just as in class definition

Alternative Definition

- Previous definition equivalent to:

```
DayOfYear::DayOfYear(                int monthValue,
                                     int dayValue)
                  : month(monthValue), day(dayValue) ←
{…}
```

- Third line called "Initialization Section"
- Body left empty
- Preferable definition version

Constructor Additional Purpose

- Not just initialize data
- Body doesn't have to be empty
  - In initializer version
- Validate the data!
  - Ensure only appropriate data is assigned to class private member variables
  - Powerful OOP principle

Overloaded Constructors

- Can overload constructors just like other functions
- Recall: a signature consists of:
  - Name of function
  - Parameter list
- Provide constructors for all possible argument-lists
  - Particularly "how many"

Class with Constructors Example: **Display 7.1** Class with Constructors (1 of 3)

Display 7.1 Class with Constructors

```
1   #include <iostream>
2   #include <cstdlib> //for exit
3   using namespace std;

4   class DayOfYear
5   {
6   public:
7       DayOfYear(int monthValue, int dayValue);
8       //Initializes the month and day to arguments.

9       DayOfYear(int monthValue);
10      //Initializes the date to the first of the given month.

11      DayOfYear( );
12      //Initializes the date to January 1.

13      void input( );
14      void output( );
15      int getMonthNumber( );
16      //Returns 1 for January, 2 for February, etc.
```

This definition of `DayOfYear` *is an improved version of the class* `DayOfYear` *given in Display 6.4.*

default constructor

Class with Constructors Example: **Display 7.1** Class with Constructors (2 of 3)

```
17      int getDay( );
18  private:
19      int month;
20      int day;
21      void testDate( );
22  };

23  int main( )
24  {
25      DayOfYear date1(2, 21), date2(5), date3;
26      cout << "Initialized dates:\n";
27      date1.output( ); cout << endl;
28      date2.output( ); cout << endl;
29      date3.output( ); cout << endl;

30      date1 = DayOfYear(10, 31);
31      cout << "date1 reset to the following:\n";
32      date1.output( ); cout << endl;
33      return 0;
34  }
35
36  DayOfYear::DayOfYear(int monthValue, int dayValue)
37                              : month(monthValue), day(dayValue)
38  {
39      testDate( );
40  }
```

This causes a call to the default constructor. Notice that there are no parentheses.

an explicit call to the constructor `DayOfYear::DayOfYear`

Class with Constructors Example:
Display 7.1 Class with Constructors (3 of 3)

Display 7.1 Class with Constructors

```
41  DayOfYear::DayOfYear(int monthValue) : month(monthValue), day(1)
42  {
43      testDate( );
44  }

45  DayOfYear::DayOfYear( ) : month(1), day(1)
46  {/*Body intentionally empty.*/}

47  //uses iostream and cstdlib:
48  void DayOfYear::testDate( )
49  {
50      if ((month < 1) || (month > 12))
51      {
52          cout << "Illegal month value!\n";
53          exit(1);
54      }
55      if ((day < 1) || (day > 31))
56      {
57          cout << "Illegal day value!\n";
58          exit(1);
59      }
60  }
```

<Definitions of the other member functions are the same as in Display 6.4.>

SAMPLE DIALOGUE

```
Initialized dates:
February 21
May 1
January 1
date1 reset to the following:
October 31
```

Constructor with No Arguments

- Can be confusing
- Standard functions with no arguments:
  - Called with syntax: callMyFunction();
    - Including empty parentheses
- Object declarations with no "initializers":
  - DayOfYear date1; // This way!
  - DayOfYear date(); // NO!
    - What is this really?
    - Compiler sees a function declaration/prototype!
    - Yes! Look closely!

Explicit Constructor Calls

- Can also call constructor AGAIN
  - After object declared
    - Recall: constructor was automatically called then
  - Can call via object's name; standard member function call
- Convenient method of setting member variables
- Method quite different from standard member function call

Explicit Constructor Call Example

- Such a call returns "anonymous object"
  - Which can then be assigned
  - **In Action**:
    DayOfYear holiday(7, 4);
    - Constructor called at object's declaration
    - Now to "re-initialize":
      holiday = DayOfYear(5, 5);
      - Explicit constructor call
      - Returns new "anonymous object"
      - Assigned back to current object

Default Constructor

- Defined as: constructor w/ no arguments
- One should always be defined
- Auto-Generated?
  - Yes & No
  - If no constructors AT ALL are defined → Yes
  - If any constructors are defined → No
- If no default constructor:
  - Cannot declare: MyClass myObject;
    - With no initializers

Class Type Member Variables

- Class member variables can be any type
  - Including objects of other classes!
  - Type of class relationship
    - Powerful OOP principle
- Need special notation for constructors
  - So they can call "back" to member object's constructor

Class Member Variable Example:
Display 7.3 A Class Member Variable (1 of 5)

Display 7.3 A Class Member Variable

```
1   #include <iostream>
2   #include<cstdlib>
3   using namespace std;

4   class DayOfYear
5   {
6   public:
7       DayOfYear(int monthValue, int dayValue);
8       DayOfYear(int monthValue);
9       DayOfYear( );
10      void input( );
11      void output( );
12      int getMonthNumber( );
13      int getDay( );
14  private:
15      int month;
16      int day;
17      void testDate( );
18  };
```

The class `DayOfYear` *is the same as in Display 7.1, but we have repeated all the details you need for this discussion.*

Class Member Variable Example:
Display 7.3 A Class Member Variable (2 of 5)

```
19  class Holiday
20  {
21  public:
22      Holiday( );//Initializes to January 1 with no parking enforcement
23      Holiday(int month, int day, bool theEnforcement);
24      void output( );
25  private:
26      DayOfYear date;
27      bool parkingEnforcement;//true if enforced
28  };

29  int main( )
30  {
31      Holiday h(2, 14, true);
32      cout << "Testing the class Holiday.\n";
33      h.output( );

34      return 0;
35  }
36
37  Holiday::Holiday( ) : date(1, 1), parkingEnforcement(false)
38  {/*Intentionally empty*/}

39  Holiday::Holiday(int month, int day, bool theEnforcement)
40                      : date(month, day), parkingEnforcement(theEnforcement)
41  {/*Intentionally empty*/}
```

member variable of a class type

Invocations of constructors from the class `DayOfYear`.

(continued)

Class Member Variable Example: **Display 7.3** A Class Member Variable (3 of 5)

Display 7.3 A Class Member Variable

```
42  void Holiday::output( )
43  {
44      date.output( );
45      cout << endl;
46      if (parkingEnforcement)
47          cout << "Parking laws will be enforced.\n";
48      else
49          cout << "Parking laws will not be enforced.\n";
50  }

51  DayOfYear::DayOfYear(int monthValue, int dayValue)
52                              : month(monthValue), day(dayValue)
53  {
54      testDate( );
55  }
```

Class Member Variable Example:
Display 7.3 A Class Member Variable (4 of 5)

```
56  //uses iostream and cstdlib:
57  void DayOfYear::testDate( )
58  {
59      if ((month < 1) || (month > 12))
60      {
61          cout << "Illegal month value!\n";
62          exit(1);
63      }
64      if ((day < 1) || (day > 31))
65      {
66          cout << "Illegal day value!\n";
67          exit(1);
68      }
69  }
70
71  //Uses iostream:
72  void DayOfYear::output( )
73  {
74      switch (month)
75      {
76          case 1:
77              cout << "January "; break;
78          case 2:
79              cout << "February "; break;
80          case 3:
81              cout << "March "; break;
                .
                .
                .
```

The omitted lines are in Display 6.3, but they are obvious enough that you should not have to look there.

Class Member Variable Example:
Display 7.3 A Class Member Variable (5 of 5)

Display 7.3 A Class Member Variable

```
82            case 11:
83                cout << "November "; break;
84            case 12:
85                cout << "December "; break;
86            default:
87                cout << "Error in DayOfYear::output. Contact software vendor.";
88        }

89        cout << day;
90    }
```

SAMPLE DIALOGUE

```
Testing the class Holiday.
February 14
Parking laws will be enforced.
```

Parameter Passing Methods

- Efficiency of parameter passing
  - Call-by-value
    - Requires copy be made → Overhead
  - Call-by-reference
    - Placeholder for actual argument
    - Most efficient method
  - Negligible difference for simple types
  - For class types → clear advantage
- Call-by-reference desirable
  - Especially for "large" data, like class types

The const Parameter Modifier

- Large data types (typically classes)
  - Desirable to use pass-by-reference
  - Even if function will not make modifications
- Protect argument
  - Use constant parameter
    - Also called constant call-by-reference parameter
  - Place keyword *const* before type
  - Makes parameter "read-only"
  - Attempt to modify parameter results in compiler error

Use of const

- All-or-nothing
- If no need for function modifications
  - Protect parameter with const
  - Protect ALL such parameters
- This includes class member function parameters

Inline Functions

- For non-member functions:
  - Use keyword *inline* in function declaration and function heading
- For class member functions:
  - Place implementation (code) for function IN class definition → automatically inline
- Use for very short functions only
- Code actually inserted in place of call
  - Eliminates overhead
  - More efficient, but only when short!

Inline Member Functions

- Member function definitions
  - Typically defined separately, in different file
  - Can be defined IN class definition
    - Makes function "in-line"
- Again: use for very short functions only
- More efficient
  - If too long → actually less efficient!

Member Initializers

- C++11 supports a feature called member initialization
  - This feature allows you to set default values for member variables

```
class Coordinate
{
  public:
        Coordinate();
  private:
        int x=1;
        int y=2;
};
Coordinate::Coordinate()
{ }

Coordinate c1;
```

Member Initializers

Initializes c1.x to 1 and c1.y to 2

Constructor Delegation

- C++11 allows one constructor to invoke another

```
Coordinate::Coordinate(int xval, int yval) : x(xval), y(yval)
{ }

Coordinate::Coordinate() : Coordinate(99,99)
{ }
```

- The default constructor invokes the constructor to initialize x and y to 99,99

Static Members

- Static member variables
  - All objects of class "share" one copy
  - One object changes it → all see change
- Useful for "tracking"
  - How often a member function is called
  - How many objects exist at given time
- Place keyword *static* before type

Static Functions

- Member functions can be static
  - If no access to object data needed
  - And still "must" be member of the class
  - Make it a static function
- Can then be called outside class
  - From non-class objects:
    - E.g., Server::getTurn();
  - As well as via class objects
    - Standard method: myObject.getTurn();
- Can only use static data, functions!

Static Members Example:
Display 7.6 Static Members (1 of 4)

Display 7.6 Static Members

```
1   #include <iostream>
2   using namespace std;

3   class Server
4   {
5   public:
6       Server(char letterName);
7       static int getTurn( );
8       void serveOne( );
9       static bool stillOpen( );
10  private:
11      static int turn;
12      static int lastServed;
13      static bool nowOpen;
14      char name;
15  };

16  int Server:: turn = 0;
17  int Server:: lastServed = 0;
18  bool Server::nowOpen = true;
```

Static Members Example:
Display 7.6 Static Members (2 of 4)

```
19  int main( )
20  {
21      Server s1('A'), s2('B');
22      int number, count;
23      do
24      {
25          cout << "How many in your group? ";
26          cin >> number;
27          cout << "Your turns are: ";
28          for (count = 0; count < number; count++)
29              cout << Server::getTurn( ) << ' ';
30          cout << endl;
31          s1.serveOne( );
32          s2.serveOne( );
33      } while (Server::stillOpen( ));

34      cout << "Now closing service.\n";

35      return 0;
36  }
37
38
```

Static Members Example: **Display 7.6** Static Members (3 of 4)

Display 7.6 Static Members

```
39  Server::Server(char letterName) : name(letterName)
40  {/*Intentionally empty*/}

41  int Server::getTurn( )
42  {
43      turn++;
44      return turn;
45  }
46  bool Server::stillOpen( )
47  {
48      return nowOpen;
49  }

50  void Server::serveOne( )
51  {
52      if (nowOpen && lastServed < turn)
53      {
54          lastServed++;
55          cout << "Server " << name
56              << " now serving " << lastServed << endl;
57       }
```

Since `getTurn` *is static, only static members can be referenced in here.*

Static Members Example:
Display 7.6 Static Members (4 of 4)

```
58        if (lastServed >= turn) //Everyone served
59            nowOpen = false;
60    }
```

SAMPLE DIALOGUE

How many in your group? **3**
Your turns are: 1 2 3
Server A now serving 1
Server B now serving 2
How many in your group? **2**
Your turns are: 4 5
Server A now serving 3
Server B now serving 4
How many in your group? **0**
Your turns are:
Server A now serving 5
Now closing service.

Vectors

- Vector Introduction
  - Recall: arrays are fixed size
  - Vectors: "arrays that grow and shrink"
    - During program execution
  - Formed from Standard Template Library (STL)
    - Using template class

Vector Basics

- Similar to array:
  - Has base type
  - Stores collection of base type values
- Declared differently:
  - Syntax: vector<Base_Type>
    - Indicates template class
    - Any type can be "plugged in" to Base_Type
    - Produces "new" class for vectors with that type
  - Example declaration:
    vector<int> v;

Vector Use

- vector<int> v;
  - "v is vector of type int"
  - Calls class default constructor
    - Empty vector object created
- Indexed like arrays for access
- But to add elements:
  - Must call member function push_back
- Member function size()
  - Returns current number of elements

Vector Example:
Display 7.7 Using a Vector (1 of 2)

Display 7.7 Using a Vector

```
1   #include <iostream>
2   #include <vector>
3   using namespace std;

4   int main( )
5   {
6       vector<int> v;
7       cout << "Enter a list of positive numbers.\n"
8            << "Place a negative number at the end.\n";

9       int next;
10      cin >> next;
11      while (next > 0)
12      {
13          v.push_back(next);
14          cout << next << " added. ";
15          cout << "v.size( ) = " << v.size( ) << endl;
16          cin >> next;
17      }
```

Vector Example:
Display 7.7 Using a Vector (2 of 2)

```
18        cout << "You entered:\n";
19        for (unsigned int i = 0; i < v.size( ); i++)
20            cout << v[i] << " ";
21        cout << endl;

22        return 0;
23    }
```

SAMPLE DIALOGUE

Enter a list of positive numbers.
Place a negative number at the end.
2 4 6 8 –1
2 added. v.size = 1
4 added. v.size = 2
6 added. v.size = 3
8 added. v.size = 4
You entered:
2 4 6 8

Vector Efficiency

- Member function capacity()
  - Returns memory currently allocated
  - Not same as size()
  - Capacity typically > size
    - Automatically increased as needed
- If efficiency critical:
  - Can set behaviors manually
    - v.reserve(32); //sets capacity to 32
    - v.reserve(v.size()+10); //sets capacity to 10 more than size

Summary 1

- Constructors: automatic initialization of class data
  - Called when objects are declared
  - Constructor has same name as class
- Default constructor has no parameters
  - Should always be defined
- Class member variables
  - Can be objects of other classes
    - Require initialization-section

Summary 2

- Constant call-by-reference parameters
  - More efficient than call-by-value
- Can *inline* very short function definitions
  - Can improve efficiency
- Static member variables
  - Shared by all objects of a class
- Vector classes
  - Like: "arrays that grow and shrink"