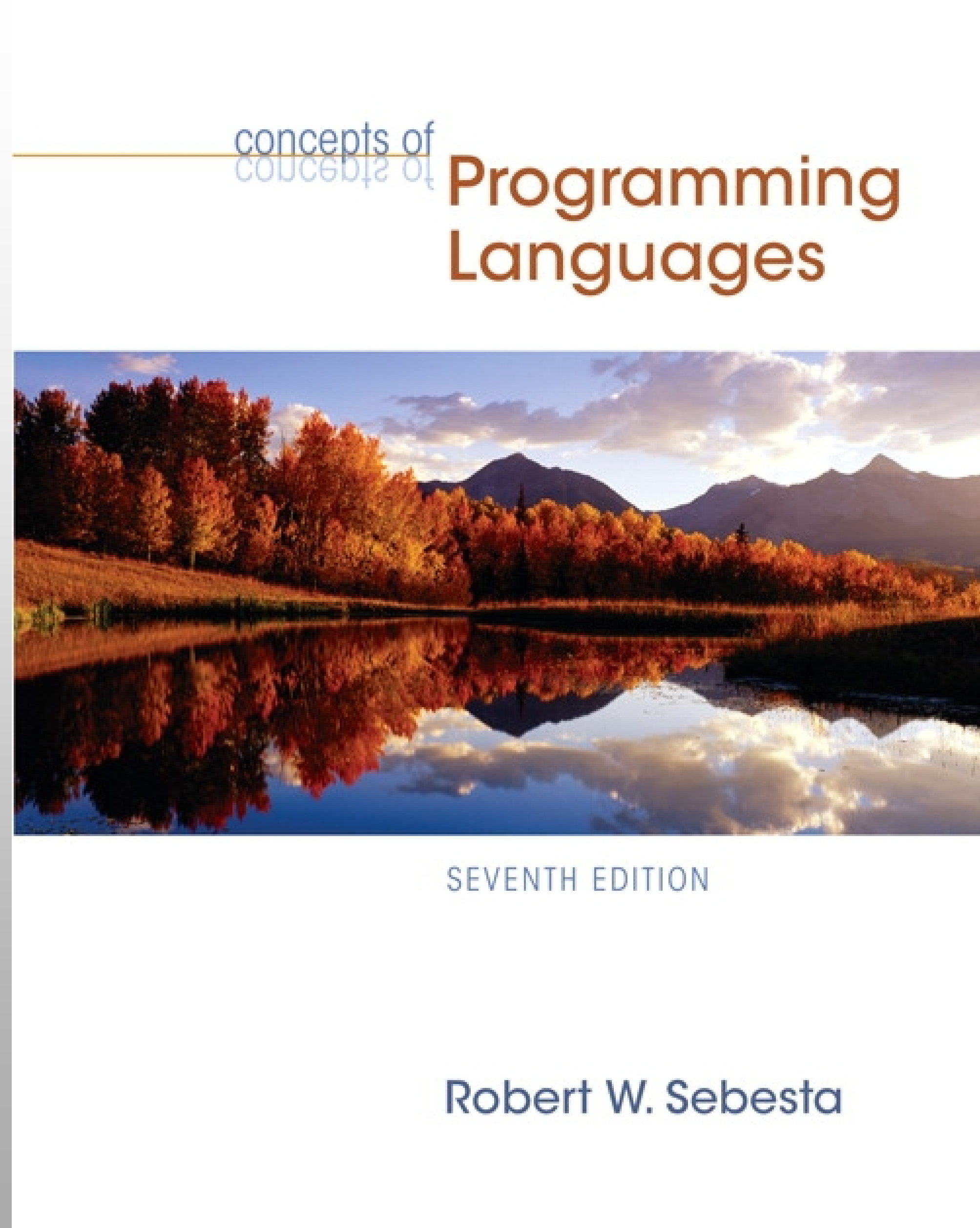
OBJECT ORIENTED PROGRAMMING USING C++

Abstract Data Types and Encapsulation Concepts



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Chapter 11 Topics

- The Concept of Abstraction
- Introduction to Data Abstraction
- Design Issues for Abstract Data Types
- Language Examples
- Parameterized Abstract Data Types
- Encapsulation Constructs
- Naming Encapsulations

The Concept of Abstraction

- An *abstraction* is a view or representation of an entity that includes only the most significant attributes
- The concept of *abstraction* is fundamental in programming (and computer science)
- Nearly all programming languages support *process abstraction* with subprograms
- Nearly all programming languages designed since 1980 support *data abstraction*

Introduction to Data Abstraction

- An *abstract data type* is a user-defined data type that satisfies the following two conditions:
  - The representation of, and operations on, objects of the type are defined in a single syntactic unit
  - The representation of objects of the type is hidden from the program units that use these objects, so the only operations possible are those provided in the type's definition

Advantages of Data Abstraction

- Advantage of the first condition
  - Program organization, modifiability (everything associated with a data structure is together), and separate compilation
- Advantage the second condition
  - Reliability--by hiding the data representations, user code cannot directly access objects of the type or depend on the representation, allowing the representation to be changed without affecting user code

Design Issues

- A syntactic unit to define an ADT
- Built-in operations
  - Assignment
  - Comparison
- Common operations
  - Iterators
  - Accessors
  - Constructors
  - Destructors
- Parameterized ADTs

Language Examples: Ada

- The encapsulation construct is called *packages*
  - Specification package (the interface)
  - Body package (implementation of the entities named in the specification)
- Information Hiding
  - The representation of type appears in a part of the specification called the *private* part
    - More restricted form with *limited private types*
  - Define the ADT as a pointer and provide the pointed-to structure's definition in the body package

An Example in Ada

```
package Stack_Pack is
   type stack_type is limited private;
   max_size: constant := 100;
   function empty(stk: in stack_type) return Boolean;
   procedure push(stk: in out stack_type; elem:in Integer);
   procedure pop(stk: in out stack_type);
   function top(stk: in stack_type) return Integer;

   private  -- hidden from clients
   type list_type is array (1..max_size) of Integer;
   type stack_type is record
       list: list_type;
       topsub: Integer range 0..max_size) := 0;
   end record;
end Stack_Pack
```

Language Examples: C++

- Based on C **`struct`** type and Simula 67 classes
- The class is the encapsulation device
- All of the class instances of a class share a single copy of the member functions
- Each instance of a class has its own copy of the class data members
- Instances can be static, stack dynamic, or heap dynamic

Language Examples: C++ (continued)

- Information Hiding
  - *Private* clause for hidden entities
  - *Public* clause for interface entities
  - *Protected* clause for inheritance

Language Examples: C++ (continued)

- Constructors:
  - Functions to initialize the data members of instances (they *do not* create the objects)
  - May also allocate storage if part of the object is heap-dynamic
  - Can include parameters to provide parameterization of the objects
  - Implicitly called when an instance is created
  - Can be explicitly called
  - Name is the same as the class name

Language Examples: C++ (continued)

- Destructors
  - Functions to cleanup after an instance is destroyed; usually just to reclaim heap storage
  - Implicitly called when the object's lifetime ends
  - Can be explicitly called
  - Name is the class name, preceded by a tilde (~)

An Example in C++

```
class stack {
  private:
      int *stackPtr, maxLen, topPtr;
  public:
      stack() { // a constructor
            stackPtr = new int [100];
            maxLen = 99;
            topPtr = -1;
      };
      ~stack () {delete [] stackPtr;};
      void push (int num) {…};
      void pop () {…};
      int top () {…};
      int empty () {…};
}
```

Evaluation of ADTs in C++ and Ada

- C++ support for ADTs is similar to expressive power of Ada
- Both provide effective mechanisms for encapsulation and information hiding
- Ada packages are more general encapsulations

Language Examples: C++ (continued)

- Friend functions or classes - to provide access to private members to some unrelated units or functions
  - Necessary in C++

Language Examples: Java

- Similar to C++, except:
  - All user-defined types are classes
  - All objects are allocated from the heap and accessed through reference variables
  - Individual entities in classes have access control modifiers (private or public), rather than clauses
  - Java has a second scoping mechanism, package scope, which can be used in place of friends
    - All entities in all classes in a package that do not have access control modifiers are visible throughout the package

An Example in Java

```
class StackClass {
  private:
      private int [] *stackRef;
      private int [] maxLen, topIndex;
      public StackClass() { // a constructor
            stackRef = new int [100];
            maxLen = 99;
            topPtr = -1;
      };
      public void push (int num) {…};
      public void pop () {…};
      public int top () {…};
      public boolean empty () {…};
}
```

Language Examples: C#

- Based on C++ and Java
- Adds two access modifiers, *internal* and *protected internal*
- All class instances are heap dynamic
- Default constructors are available for all classes
- Garbage collection is used for most heap objects, so destructors are rarely used
- `structs` are lightweight classes that do not support inheritance

Language Examples: C# (continued)

- Common solution to need for access to data members: accessor methods (getter and setter)
- C# provides *properties* as a way of implementing getters and setters without requiring explicit method calls

C# Property Example

```
public class Weather {
   public int DegreeDays { //** DegreeDays is a property
      get {return degreeDays;}
      set {degreeDays = value;}
   }
   private int degreeDays;
   ...
   }
...
Weather w = new Weather();
int degreeDaysToday, oldDegreeDays;
...
w.DegreeDays = degreeDaysToday;
...
oldDegreeDays = w.DegreeDays;
```

Parameterized Abstract Data Types

- Parameterized ADTs allow designing an ADT that can store any type elements
- Also known as generic classes
- C++ and Ada provide support for parameterized ADTs
- Java 5.0 provides a restricted form of parameterized ADTs
- C# does not currently support parameterized classes

Parameterized ADTs in Ada

- Ada Generic Packages
  - Make the stack type more flexible by making the element type and the size of the stack generic

```
generic
Max_size: Positive;
type Elem_Type is Private;
package Generic_Stack is
…
function Top(Stk: in out StackType) return Elem_type;
…
end Generic_Stack;
```

```
Package Integer_Stack is new Generics_Stack(100,Integer);
Package Float_Stack is new Generics_Stack(100,Float);
```

Parameterized ADTs in C++

- Classes can be somewhat generic by writing parameterized constructor functions

```
template <class type>
class stack {
…
 stack (int size) {
 stk_ptr = new int [size];
 max_len = size - 1;
  top = -1;
 };
 …
}

 stack stk(100);
```

Encapsulation Constructs

- Large programs have two special needs:
  - Some means of organization, other than simply division into subprograms
  - Some means of partial compilation (compilation units that are smaller than the whole program)
- Obvious solution: a grouping of subprograms that are logically related into a unit that can be separately compiled (compilation units)
- Such collections are called *encapsulation*

Nested Subprograms

- Organizing programs by nesting subprogram definitions inside the logically larger subprograms that use them
- Nested subprograms are supported in Ada and Fortran 95

Encapsulation in C

- Files containing one or more subprograms can be independently compiled
- The interface is placed in a *header file*
- Problem: the linker does not check types between a header and associated implementation
- `#include` preprocessor specification

Encapsulation in C++

- Similar to C
- Addition of *friend* functions that have access to private members of the friend class

Ada Packages

- Ada specification packages can include any number of data and subprogram declarations
- Ada packages can be compiled separately
- A package's specification and body parts can be compiled separately

C# Assemblies

- A collection of files that appear to be a single dynamic link library or executable
- Each file contains a module that can be separately compiled
- A DLL is a collection of classes and methods that are individually linked to an executing program
- C# has an access modifier called `internal`; an `internal` member of a class is visible to all classes in the assembly in which it appears

Naming Encapsulations

- Large programs define many global names; need a way to divide into logical groupings
- A *naming encapsulation* is used to create a new scope for names
- C++ Namespaces
  - Can place each library in its own namespace and qualify names used outside with the namespace
  - C# also includes namespaces

Naming Encapsulations (continued)

- Java Packages
  - Packages can contain more than one class definition; classes in a package are *partial* friends
  - Clients of a package can use fully qualified name or use the ***`import`*** declaration
- Ada Packages
  - Packages are defined in hierarchies which correspond to file hierarchies
  - Visibility from a program unit is gained with the `with` clause

Summary

- The concept of ADTs and their use in program design was a milestone in the development of languages
- Two primary features of ADTs are the packaging of data with their associated operations and information hiding
- Ada provides packages that simulate ADTs
- C++ data abstraction is provided by classes
- Java's data abstraction is similar to C++
- Ada and C++ allow parameterized ADTs
- C++, C#, Java, and Ada provide naming encapsulation