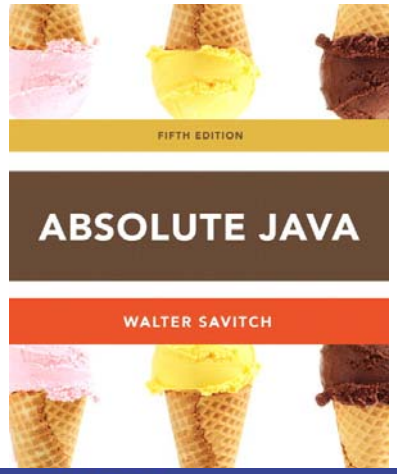

Chapter 12

UML and Patterns

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Introduction to UML and Patterns

- UML and patterns are two software design tools that can be used within the context of any OOP language
- UML is a graphical language used for designing and documenting OOP software
- A pattern in programming is a kind of template or outline of a software task
  - A pattern can be realized as different code in different, but similar, applications

UML

- Pseudocode is a way of representing a program in a linear and algebraic manner
  - It simplifies design by eliminating the details of programming language syntax
- Graphical representation systems for program design have also been used
  - *Flowcharts* and *structure diagrams* for example
- *Unified Modeling Language* (*UML*) is yet another graphical representation formalism
  - UML is designed to reflect and be used with the OOP philosophy

History of UML

- As OOP has developed, different groups have developed graphical or other representations for OOP design
- In 1996, Brady Booch, Ivar Jacobson, and James Rumbaugh released an early version of UML
  - Its purpose was to produce a standardized graphical representation language for object-oriented design and documentation
- Since then, UML has been developed and revised in response to feedback from the OOP community
  - Today, the UML standard is maintained and certified by the Object Management Group (OMG)

UML Class Diagrams

- Classes are central to OOP, and the *class diagram* is the easiest of the UML graphical representations to understand and use
- A class diagram is divided up into three sections
  - The top section contains the class name
  - The middle section contains the data specification for the class
  - The bottom section contains the actions or methods of the class

UML Class Diagrams

- The data specification for each piece of data in a UML diagram consists of its name, followed by a colon, followed by its type
- Each name is preceded by a character that specifies its access type:
  - A minus sign (-) indicates private access
  - A plus sign (+) indicates public access
  - A sharp (#) indicates protected access
  - A tilde (~) indicates package access

UML Class Diagrams

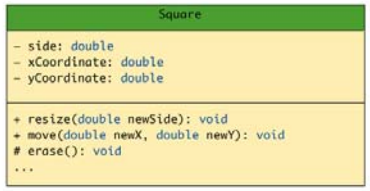
- Each method in a UML diagram is indicated by the name of the method, followed by its parenthesized parameter list, a colon, and its return type
- The access type of each method is indicated in the same way as for data

UML Class Diagrams

- A class diagram need not give a complete description of the class
  - If a given analysis does not require that all the class members be represented, then those members are not listed in the class diagram
  - Missing members are indicated with an ellipsis (three dots)

A UML Class Diagram

Display 12.1 **A UML Class Diagram**



Class Interactions

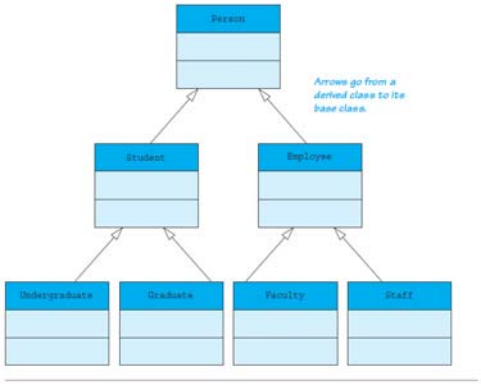
- Rather than show just the interface of a class, class diagrams are primarily designed to show the interactions among classes
- UML has various ways to indicate the information flow from one class object to another using different sorts of annotated arrows
- UML has annotations for class groupings into packages, for inheritance, and for other interactions
- In addition to these established annotations, UML is extensible

Inheritance Diagrams

- An *inheritance diagram* shows the relationship between a base class and its derived class(es)
  - Normally, only as much of the class diagram is shown as is needed
  - Note that each derived class may serve as the base class of its derived class(es)
- Each base class is drawn above its derived class(es)
  - An upward pointing arrow is drawn between them to indicate the inheritance relationship

A Class Hierarchy in UML Notation

Display 12.2 A Class Hierarchy in UML Notation

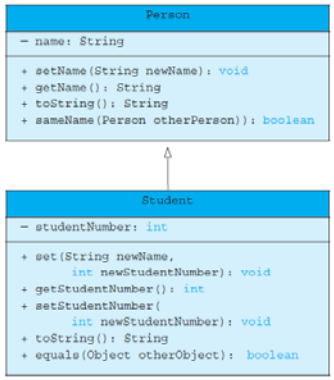


Inheritance Diagrams

- The arrows also help in locating method definitions
- To look for a method definition for a class:
  - Examine the class definition first
  - If the method is not found, the path of connecting arrows will show the order and direction in which to search
  - Examine the parent class indicated by the connecting arrow
  - If the method is still not found, then examine this parent's parent class indicated by the connecting arrow
  - Continue until the method is found, or until the top base class is reached

Some Details of a UML Class Hierarchy

Display 12.3 Some Details of a UML Class Hierarchy



Patterns

- *Patterns* are design outlines that apply across a variety of software applications
  - To be useful, a pattern must apply across a variety of situations
  - To be substantive, a pattern must make some assumptions about the domain of applications to which it applies

Container-Iterator Pattern

- A *container* is a class or other construct whose objects hold multiple pieces of data
  - An array is a container
  - Vectors and linked lists are containers
  - A String value can be viewed as a container that contains the characters in the string
- Any construct that can be used to cycle through all the items in a container is an *iterator*
  - An array index is an iterator for an array
- The *Container-Iterator* pattern describes how an iterator is used on a container

Adaptor Pattern

- The Adaptor pattern transforms one class into a different class without changing the underlying class, but by merely adding a new interface
  - For example, one way to create a stack data structure is to start with an array, then add the stack interface

The Model-View-Controller Pattern

- The *Model-View-Controller* pattern is a way of separating the I/O task of an application from the rest of the application
  - The Model part of the pattern performs the heart of the application
  - The View part displays (outputs) a picture of the Model's state
  - The Controller is the input part: It relays commands from the user to the Model

The Model-View-Controller Pattern

- Each of the three interacting parts is normally realized as an object with responsibilities for its own tasks
- The Model-View-Controller pattern is an example of a divide-and-conquer strategy
  - One big task is divided into three smaller tasks with well-defined responsibilities

The Model-View-Controller Pattern

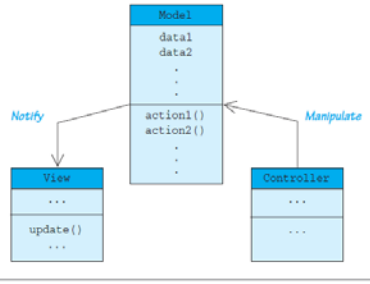
- As an example, the Model might be a container class, such as an array.
- The View might display one element of the array
- The Controller would give commands to display the element at a specified index
- The Model would notify the View to display a new element whenever the array contents changed or a different index location was given

The Model-View-Controller Pattern

- Any application can be made to fit the Model-View-Controller pattern, but it is particularly well suited to GUI (Graphical User Interface) design projects
  - The View can then be a visualization of the state of the Model

Model-View-Controller Pattern

Display 12.4 Model-View-Controller Pattern



A Sorting Pattern

- The most efficient sorting algorithms all seem to follow a divide-and-conquer strategy
- Given an array `a`, and using the `<` operator, these sorting algorithms:
  - Divide the list of elements to be sorted into two smaller lists (`split`)
  - Recursively sort the two smaller lists (`sort`)
  - Then recombine the two sorted lists (`join`) to obtain the final sorted list

A Sorting Pattern

- The method `split` rearranges the elements in the interval `a[begin]` through `a[end]` and divides the rearranged interval at `splitPoint`
- The two smaller intervals are then sorted by a recursive call to the method `sort`
- After the two smaller intervals are sorted, the method `join` combines them to obtain the final sorted version of the entire larger interval
- Note that the pattern does not say exactly how the methods `split` and `join` are defined
  - Different definitions of `split` and `join` will yield different sorting algorithms

Divide-and-Conquer Sorting Pattern

Display 12.5 **Divide-and-Conquer Sorting Pattern**

```
1  /**
2   Precondition: Interval a[begin] through a[end] of a have elements.
3   Postcondition: The values in the interval have
4   been rearranged so that a[begin] <= a[begin+1] <= ... <= a[end].
5  */
6  public static void sort(Type[] a, int begin, int end)
7  {
8      if ((end - begin) >= 1)
9      {
10         int splitPoint = split(a, begin, end);
11         sort(a, begin, splitPoint);
12         sort(a, splitPoint + 1, end);
13         join(a, begin, splitPoint, end);
14     }//else sorting one (or fewer) elements so do nothing.
15 }
```

To get a correct Java method definition Type must be replaced with a suitable type name.

Different definitions for the methods split and join will give different realizations of this pattern.

Merge Sort

- The simplest realization of this sorting pattern is the *merge sort*
- The definition of **`split`** is very simple
  - It divides the array into two intervals without rearranging the elements
- The definition of **`join`** is more complicated
- Note: There is a trade-off between the complexity of the methods **`split`** and **`join`**
  - Either one can be made simpler at the expense of making the other more complicated

Merge Sort: the **`join`** method

- The merging starts by comparing the smallest elements in each smaller sorted interval
- The smaller of these two elements is the smallest of all the elements in either subinterval
- The method **`join`** makes use of a temporary array, and it is to this array that the smaller element is moved
- The process is repeated with the remaining elements in the two smaller sorted intervals to find the next smallest element, and so forth

Merge Sort Code (1 of 3)

```
/**
 Class that realizes the divide-and-conquer sorting pattern and
 uses the merge sort algorithm.
*/
public class MergeSort
{

    /**
     Precondition: Interval a[begin] through a[end] of a have elements.
     Postcondition: The values in the interval have
     been rearranged so that a[begin] <= a[begin+1] <= ... <= a[end].
    */
    public static void sort(double[] a, int begin, int end)
    {
        if ((end - begin) >= 1)
        {
            int splitPoint = split(a, begin, end);
            sort(a, begin, splitPoint);
            sort(a, splitPoint + 1, end);
            join(a, begin, splitPoint, end);
        }//else sorting one (or fewer) elements so do nothing.
    }
```

Merge Sort Code (2 of 3)

```
private static int split(double[] a, int begin, int end)
{
    return ((begin + end)/2);
}

private static void join(double[] a, int begin, int splitPoint, int end)
{
    double[] temp;
    int intervalSize = (end - begin + 1);
    temp = new double[intervalSize];
    int nextLeft = begin; //index for first chunk
    int nextRight = splitPoint + 1; //index for second chunk
    int i = 0; //index for temp

    //Merge till one side is exhausted:
    while ((nextLeft <= splitPoint) && (nextRight <= end))
    {
        if (a[nextLeft] < a[nextRight])
        {
            temp[i] = a[nextLeft];
            i++; nextLeft++;
        }

        else
        {
            temp[i] = a[nextRight];
            i++; nextRight++;
        }
    }
```


Merge Sort Code (3 of 3)

```
    while (nextLeft <= splitPoint)//Copy rest of left chunk, if any.
        {
            temp[i] = a[nextLeft];
            i++; nextLeft++;
        }

        while (nextRight <= end) //Copy rest of right chunk, if any.
        {
            temp[i] = a[nextRight];
            i++; nextRight++;
        }

        for (i = 0; i < intervalSize; i++)
            a[begin + i] = temp[i];
    }

}
```


Merge Sort Demo

```
public class MergeSortDemo
{
    public static void main(String[] args)
    {
        double[] b = {7.7, 5.5, 11, 3, 16, 4.4, 20, 14, 13, 42};

        System.out.println("Array contents before sorting:");
        int i;
        for (i = 0; i < b.length; i++)
            System.out.print(b[i] + " ");
        System.out.println( );

        MergeSort.sort(b, 0, b.length-1);
        System.out.println("Sorted array values:");
        for (i = 0; i < b.length; i++)
            System.out.print(b[i] + " ");
        System.out.println( );
    }
}
```


Quick Sort

- In the *quick sort* realization of the sorting pattern, the definition of **`split`** is quite sophisticated, while **`join`** is utterly simple
  - First, a value called the *splitting value* is chosen
    - We do this arbitrarily but other methods to select this value may be employed
  - The elements in the array are rearranged:
    - All elements less than or equal to the splitting value are placed at the front of the array
    - All elements greater than the splitting value are placed at the back of the array
    - The splitting value is placed in between the two

Quick Sort

- Note that the smaller elements are not sorted, and the larger elements are not sorted
  - However, all the elements before the splitting value are smaller than any of the elements after the splitting value
- The smaller elements are then sorted by a recursive call, as are the larger elements
- Then these two sorted segments are combined
  - The **`join`** method actually does nothing

Quick Sort Code (1 of 3)

```
public class QuickSort
{
    /**
     Precondition: Interval a[begin] through a[end] of a have elements.
     Postcondition: The values in the interval have
     been rearranged so that a[begin] <= a[begin+1] <= ... <= a[end].
    */
    public static void sort(double[] a, int begin, int end)
    {
        if ((end - begin) >= 1)
        {
            int splitPoint = split(a, begin, end);
            sort(a, begin, splitPoint);
            sort(a, splitPoint + 1, end);
            join(a, begin, splitPoint, end);
        }//else sorting one (or fewer) elements so do nothing.
    }

    private static int split(double[] a, int begin, int end)
    {
        double[] temp;
        int size = (end - begin + 1);
        temp = new double[size];

        double splitValue = a[begin];
        int up = 0;
        int down = size - 1;
```


Quick Sort Code (2 of 3)

```
        //Note that a[begin] = splitValue is skipped.
        for (int i = begin + 1; i <= end; i++)
        {
            if (a[i] <= splitValue)
            {
                temp[up] = a[i];
                up++;
            }
            else
            {
                temp[down] = a[i];
                down--;
            }
        }

        //0 <= up = down < size

        temp[up] = a[begin]; //Positions the split value, spliV.

        //temp[i] <= splitValue for i < up
         // temp[up] = splitValue
         // temp[i] > splitValue for i > up

        for (int i = 0; i < size; i++)
            a[begin + i] = temp[i];

        return (begin + up);
    }
```


Quick Sort Code (3 of 3)

```
  private static void join(double[] a, int begin,
                           int splitPoint, int end)
    {
        //Nothing to do.
    }

 }

 public class QuickSortDemo
 {
    public static void main(String[] args)
    {
        double[] b = {7.7, 5.5, 11, 3, 16, 4.4, 20, 14, 13, 42};

        System.out.println("Array contents before sorting:");
        int i;
        for (i = 0; i < b.length; i++)
            System.out.print(b[i] + " ");
        System.out.println( );

        QuickSort.sort(b, 0, b.length-1);
        System.out.println("Sorted array values:");
        for (i = 0; i < b.length; i++)
            System.out.print(b[i] + " ");
        System.out.println( );
    }
 }
```

Restrictions on the Sorting Pattern

- Like all patterns, the sorting pattern has some restrictions on where it applies
  - It applies only to types for which the `<` operator is defined
  - It applies only to sorting into increasing order
- The pattern can be made more general, however
  - The `<` operator can be replaced with a `boolean` valued method called `compare`
  - The `compare` method would take two arguments of the base type of the array, and return `true` or `false` based on the comparison criteria

Efficiency of the Sorting Pattern

- The most efficient implementations of the sorting pattern are those for which the `split` method divides the array into two substantial size chunks
  - The merge sort `split` divides the array into two roughly equal parts, and is very efficient
  - The quick sort `split` may or may not divide the array into two roughly equal parts
    - When it does not, its worst-case running time is not as fast as that of merge sort

Efficiency of the Sorting Pattern

- The selection sort algorithm (from Chapter 5) divides the array into two pieces: one with a single element, and one with the rest of the array interval
  - Because of this uneven division, selection sort has a poor running time
  - However, it is simple

Pragmatics and Patterns

- Patterns are guides, not requirements
  - It is not necessary to follow all the fine details
- For example, quick sort was described by following the sorting pattern exactly
  - Notice that, despite the fact that method calls incur overhead, the quick sort `join` method does nothing
  - In practice calls to `join` would be eliminated
  - Other optimizations can also be done once the general pattern of an algorithm is clear