Chapter 8
Arrays

Java Software Solutions
Foundations of Program Design
Seventh Edition

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Arrays

• Arrays are objects that help us organize large amounts of information

• Chapter 8 focuses on:
  – array declaration and use
  – bounds checking and capacity
  – arrays that store object references
  – variable length parameter lists
  – multidimensional arrays
  – polygons and polylines
  – mouse events and keyboard events
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Mouse Events and Key Events
Arrays

- The ArrayList class, introduced in Chapter 5, is used to organize a list of objects

- It is a class in the Java API

- An array is a programming language construct used to organize a list of objects (so what is the difference?)

- It has special syntax to access elements

- As its name implies, the ArrayList class uses an array internally to manage the list of objects
Arrays

• An array is an ordered list of values:

The entire array has a single name

Each value has a numeric *index*

scores

0  1  2  3  4  5  6  7  8  9
79  87  94  82  67  98  87  81  74  91

An array of size N is indexed from zero to N-1

This array holds 10 values that are indexed from 0 to 9
Arrays

• A particular value in an array is referenced using the array name followed by the index in brackets.

• For example, the expression `scores[2]`

  refers to the value 94 (the 3rd value in the array – see previous slide)

• That expression represents a place to store a single integer and can be used wherever an integer variable can be used.
Arrays

• For example, an array element can be assigned a value, printed, or used in a calculation:

    scores[2] = 89;
    scores[first] = scores[first] + 2;
    mean = (scores[0] + scores[1])/2;
    System.out.println ("Top = " + scores[5]);
    pick = scores[rand.nextInt(11)];
Arrays

- The values held in an array are called *array elements*

- An array stores multiple values *of the same type* – the *element type*

- The element type can be a *primitive type* or an *object reference*

- Therefore, we can create an array of integers, an array of characters, an array of *String objects*, an array of *Coin objects*, etc.
Arrays

- In Java, the **array** itself is an **object** that must be instantiated.
- Another way to depict the **scores** array:

<p>| | | |</p>
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<thead>
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<tbody>
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<td>87</td>
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</tbody>
</table>

  The name of the array is an object reference variable.
Declaring Arrays

• The `scores` array could be declared as follows:

```java
int[] scores = new int[10];
```

• The type of the variable `scores` is `int[]` (an array of integers)

• Note that the array type does not specify its size, but each object of that type has a specific size

• The reference variable `scores` is set to a new array object that can hold 10 integers
Declaring Arrays

• Some other examples of array declarations:

    int[] weights = new int[2000];
    double[] prices = new double[500];
    boolean[] flags;
    char[] codes = new char[1750];
    flags = new boolean[20];
Using Arrays

• The for-each version of the for loop can be used when processing array elements:

```java
for (int score : scores)
    System.out.println(score);
```

• This is only appropriate when processing all array elements starting at index 0

• *It can't be used to set the array values (why?)*

• See BasicArray.java
public class BasicArray
{
  //-------------------------------
  //  Creates an array, fills it with various integer values,
  //  modifies one value, then prints them out.
  //-------------------------------
  public static void main (String[] args)
  {
    final int LIMIT = 15, MULTIPLE = 10;

    int[] list = new int[LIMIT];

    // Initialize the array values
    for (int index = 0; index < LIMIT; index++)
      list[index] = index * MULTIPLE;

    list[5] = 999;  // change one array value

    // Print the array values
    for (int value : list)
      System.out.print (value + " ");
  }
}
public class BasicArray
{
    //--------------------------------------------------------------------
    //  Creates an array, fills it with various integer values,
    //  modifies one value, then prints them out.
    //--------------------------------------------------------------------
    public static void main (String[] args)
    {
        final int LIMIT = 15, MULTIPLE = 10;

        int[] list = new int[LIMIT];

        // Initialize the array values
        for (int index = 0; index < LIMIT; index++)
            list[index] = index * MULTIPLE;

        list[5] = 999;  // change one array value

        // Print the array values
        for (int value : list)
            System.out.print (value + "  ");
    } 
}
Basic Array Example

<table>
<thead>
<tr>
<th>The array is created with 15 elements, indexed from 0 to 14</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<th>After changing the value of list[5]</th>
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Quick Check

Write an array declaration to represent the ages of 100 children.

Write code that prints each value in an array of integers named values.
Quick Check

Write an array declaration to represent the ages of 100 children.

```java
int[] ages = new int[100];
```

Write code that prints each value in an array of integers named `values`.

```java
for (int value : values) System.out.println(value);
```
Quiz

Which of the following loops would adequately add 1 to each element stored in values?

A) for (j=1; j<values.length; j++) values[j]++;
B) for (j=0; j<values.length; j++) values[j]++;
C) for (j=0; j<=values.length; j++) values[j]++;
D) for (j=0; j<values.length-1; j++) values[j]++;
E) for (j=1; j<values.length-1; j++) values[j]++;
Quiz

Which of the following loops would adequately add 1 to each element stored in values?

A) for (j=1; j<values.length; j++)  values[j]++;
B) for (j=0; j<values.length; j++)  values[j]++;
C) for (j=0; j<=values.length; j++)  values[j]++;
D) for (j=0; j<values.length-1; j++) values[j]++;
E) for (j=1; j<values.length-1; j++)  values[j]++;

The first array element is values[0], so the for-loop must start at 0, not 1. There are values.length elements in the array where the last element is at values.length-1, so the for loop must stop before reaching values.length.
Bounds Checking

• Once an array is created, it has a **fixed size** (e.g. N)

• An **index** used in an array reference **must specify a valid element**

• That is, the index value must be in range 0 to N-1

• The Java interpreter throws an `ArrayIndexOutOfBoundsException` if an array index is out of bounds

• This is called automatic **bounds checking**
Bounds Checking

• For example, if the array `codes` can hold 100 values, it can be indexed from 0 to 99

• If the value of `count` is 100, then the following reference will cause an exception to be thrown:

  ```java
  System.out.println(codes[count]);
  ```

• It’s common to introduce off-by-one errors when using arrays:

  ```java
  for (int index=0; index <= 100; index++)
      codes[index] = index*50 + epsilon;
  ```

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Bounds Checking

• Each array object has a public constant called `length` that stores the size of the array

• It is referenced using the array name:
  
  `scores.length`

• Note that `length` holds the number of elements, not the largest index

• See `ReverseOrder.java`

• See `LetterCount.java`
import java.util.Scanner;

public class ReverseOrder
{
    // Demonstrates array index processing.
    //Reads a list of numbers from the user, storing them in an array, then prints them in the opposite order.
    public static void main (String[] args)
    {
        Scanner scan = new Scanner (System.in);

        double[] numbers = new double[10];

        System.out.println ("The size of the array: " + numbers.length);

        continue
```java
continue

   for (int index = 0; index < numbers.length; index++)
   {
       System.out.print("Enter number "+ (index+1) + ": ");
       numbers[index] = scan.nextDouble();
   }

System.out.println("The numbers in reverse order:");

   for (int index = numbers.length-1; index >= 0; index--)
   {
       System.out.print(numbers[index] + "  ");
   }
```
Sample Run

The size of the array: 10
Enter number 1: 18.36
Enter number 2: 48.9
Enter number 3: 53.5
Enter number 4: 29.06
Enter number 5: 72.404
Enter number 6: 34.8
Enter number 7: 63.41
Enter number 8: 45.55
Enter number 9: 69.0
Enter number 10: 99.18
The numbers in reverse order:
99.18  69.0  45.55  63.41  34.8  72.404  29.06  53.5  48.9  18.36
import java.util.Scanner;

public class LetterCount {
    public static void main (String[] args)
    {
        final int NUMCHARS = 26;

        Scanner scan = new Scanner (System.in);

        int[] upper = new int[NUMCHARS];
        int[] lower = new int[NUMCHARS];

        char current;  // the current character being processed
        int other = 0;  // counter for non-alphabetics

        continue
System.out.println("Enter a sentence:");
String line = scan.nextLine();

// Count the number of each letter occurrence
for (int ch = 0; ch < line.length(); ch++)
{
    current = line.charAt(ch);
    if (current >= 'A' && current <= 'Z')
        upper[current-'A']++;
    else
        if (current >= 'a' && current <= 'z')
            lower[current-'a']++;
        else
            other++;
}

continue
// Print the results
System.out.println();
for (int letter=0; letter < upper.length; letter++)
{
    System.out.print((char)(letter + 'A'));
    System.out.print(":: " + upper[letter]);
    System.out.print("\t\t" + (char)(letter + 'a'));
    System.out.println(":: " + lower[letter]);
}
System.out.println();
System.out.println("Non-alphabetic characters: " + other);
Sample Run

Enter a sentence:
In Casablanca, Humphrey Bogart never says "Play it again, Sam."

A: 0    a: 10
B: 1    b: 1
C: 1    c: 1
D: 0    d: 0
E: 0    e: 3
F: 0    f: 0
G: 0    g: 2
H: 1    h: 1
I: 1    i: 2
J: 0    j: 0
K: 0    k: 0
L: 0    l: 2
M: 0    m: 2
N: 0    n: 4
O: 0    o: 1
P: 1    p: 1
Q: 0    q: 0

Sample Run (continued)

R: 0    r: 3
S: 1    s: 3
T: 0    t: 2
U: 0    u: 1
V: 0    v: 1
W: 0    w: 0
X: 0    x: 0
Y: 0    y: 3
Z: 0    z: 0

Non-alphabetic characters: 14
Quiz

To swap the 3rd and 4th elements in the int array values, you would do:

```c
values[3] = values[4];
values[4] = values[3];
```

True or False?
Quiz

To swap the 3rd and 4th elements in the int array values, you would do:

```c
values[3] = values[4];
values[4] = values[3];
```

False

```c
int temp = values[3];
values[3] = values[4];
values[4] = temp;
```
Quiz

• Implement a class ArrayUtil with a static method that checks if two arrays of integers are equal, i.e., they contain the same elements (return a boolean)
public class ArrayUtil {

    public static boolean equals(int[] a1, int[] a2) {
        if (a1.length != a2.length) {
            return false;
        }
        for (int i = 0; i < a1.length; i++) {
            if (a1[i] != a2[i]) {
                return false;
            }
        }
        return true;
    }
}

Quiz

• Implement a class ArrayUtil with a static method that checks if two arrays of integers are equal, i.e., they contain the same elements (return a boolean)
A "better" solution

```java
public static boolean equals(int[] a1, int[] a2) {
    boolean res = false;
    if (a1.length == a2.length) {
        res = true;
        int size = a1.length;
        while (res && size > 0) {
            size--;
            res = a1[size] == a2[size];
        }
    }
    return res;
}
```

There is only one return statement.
Alternate Array Syntax

- The brackets of the array type can be associated with the element type or with the name of the array.
- Therefore the following two declarations are equivalent:

  ```
  double[] prices;
  double prices[];
  ```

- The first format generally is more readable and should be used.
Quiz

Given the following declarations, which of the following variables are arrays?

\[
\text{int}\[\ ]\ a, \ b; \\
\text{int} \ c, \ d[\ ];
\]

A) a  
B) a and b  
C) a and d  
D) a, b and d  
E) a, b, c and d
Quiz

Given the following declarations, which of the following variables are arrays?

```java
int[ ] a, b;
int c, d[ ];
```

A) a
B) a and b
C) a and d
D) a, b and d
E) a, b, c and d

The first declaration declares both a and b to be int arrays. The second declaration declares c and d to be ints but in the case of d, an int array.
Initializer Lists

- An *initializer list* can be used to instantiate and fill an array in one step
- The values are delimited by braces and separated by commas
- Examples:

  ```
  int[] units = {147, 323, 89, 933, 540, 269, 97, 114, 298, 476};
  char[] grades = {'A', 'B', 'C', 'D', 'F'};
  ```
Initializer Lists

- Note that when an initializer list is used:
  - the `new` operator is not used
  - no size value is specified

- The size of the array is determined by the number of items in the list

- An initializer list can be used only in the array declaration

- See `Primes.java`
```java
public class Primes {
  
  // Stores some prime numbers in an array and prints them.
  public static void main (String[] args) {
    int[] primeNums = {2, 3, 5, 7, 11, 13, 17, 19};
    System.out.println ("Array length: " + primeNums.length);
    System.out.println ("The first few prime numbers are:");
    for (int prime : primeNums) {
      System.out.print (prime + " ");
    }
  }
}
```
public class Primes
{
    // Stores some prime numbers in an array and prints them.
    public static void main (String[] args)
    {
        int[] primeNums = {2, 3, 5, 7, 11, 13, 17, 19};

        System.out.println ("Array length: " + primeNums.length);

        System.out.println ("The first few prime numbers are:");

        for (int prime : primeNums)
        {
            System.out.print (prime + " ");
        }
    }
}
Arrays as Parameters

• An entire array can be passed as a parameter to a method.

• Like any other object, the reference to the array is passed, making the formal and actual parameters aliases of each other.

• Therefore, changing an array element within the method changes the original.

• An individual array element can be passed to a method as well, in which case the type of the formal parameter is the same as the element type.
Example

... 

public static void main (String[] args) {
    int[] myArray = {1,2,3};
    foo(myArray);
    for(int value : myArray)
        System.out.println(value);
}

private static void foo(int[] values) {
    values[0] = 0;
}

...

What is going to be printed by the main method?
Quiz

In Java, arrays are
A) primitive data types
B) objects
C) interfaces
D) primitive data types if the type stored in the array is a primitive data type and objects if the type stored in the array is an object
E) Strings
Quiz

In Java, arrays are
A) primitive data types
B) objects
C) interfaces
D) primitive data types if the type stored in the array is a primitive data type and objects if the type stored in the array is an object
E) Strings

In Java, arrays are implemented as objects. The variable is a reference variable to the block of memory that stores the entire array. However, arrays are accessed using the notation name[index] rather than by message passing (method invocation).
Quiz

What does the following code do? Assume list is an array of int values, temp is some previously initialized int value, and c is an int initialized to 0.

```cpp
for (int j = 0; j < list.length; j++)
    if (list[j] < temp) c++;
```

A) It finds the smallest value and stores it in temp
B) It finds the largest value and stores it in temp
C) It counts the number of elements equal to the smallest value in list
D) It counts the number of elements in list that are less than temp
E) It sorts the values in list to be in ascending order
Quiz

What does the following code do? Assume list is an array of int values, temp is some previously initialized int value, and c is an int initialized to 0.

```java
for (int j = 0; j < list.length; j++)
    if (list[j] < temp) c++;
```

A) It finds the smallest value and stores it in temp
B) It finds the largest value and stores it in temp
C) It counts the number of elements equal to the smallest value in list
D) It counts the number of elements in list that are less than temp
E) It sorts the values in list to be in ascending order
Outline

Declaring and Using Arrays

Arrays of Objects

Variable Length Parameter Lists

Two-Dimensional Arrays

Polygons and Polylines

Mouse Events and Key Events
Arrays of Objects

• The **elements** of an array can be **object references**

• The following declaration reserves space to store 5 **references** to **String objects**

  ```java
  String[] words = new String[5];
  ```

• It does NOT create the **String objects** themselves

• **Initially** an array of objects holds **null references**

• Each **object** stored in an array **must be instantiated separately**
Arrays of Objects

• The `words` array when initially declared:

```java
// Code snippet
System.out.println(words[0]);
```

Actually, this is false: it will print `null`. All the references `words[1],..., words[5]` point to `null`. 
Arrays of Objects

• After some String objects are created and stored in the array:
Arrays of Objects

• Keep in mind that \texttt{String} objects can be created using literals (e.g. "I am a literal")

• The following declaration creates an array object called \texttt{verbs} and fills it with four \texttt{String} objects created using string literals

\begin{verbatim}
String[] verbs = {"play", "work", "eat", 
"sleep", "run"};
\end{verbatim}
Arrays of Objects

• The following example creates an array of Grade objects, each with a string representation and a numeric lower bound

• The letter grades include plus and minus designations, so must be stored as strings instead of char

• See GradeRange.java
• See Grade.java
public class GradeRange
{
    //---................................................................
    //  Creates an array of Grade objects and prints them.
    //---................................................................
    public static void main (String[] args)
    {
        Grade[] grades =
        {
            new Grade("A", 95), new Grade("A-", 90),
            new Grade("B+", 87), new Grade("B", 85),
            new Grade("B-", 80),
            new Grade("C+", 77), new Grade("C", 75),
            new Grade("C-", 70),
            new Grade("D+", 67), new Grade("D", 65),
            new Grade("D-", 60),
            new Grade("F", 0)
        };

        for (Grade letterGrade : grades)
            System.out.println (letterGrade);
    }
}
public class GradeRange
{
    // Creates an array of Grade objects and prints them.
    public static void main (String[] args)
    {
        Grade[] grades = {
            new Grade("A", 95),
            new Grade("A-", 90),
            new Grade("B+", 87),
            new Grade("B", 85),
            new Grade("B-", 80),
            new Grade("C+", 77),
            new Grade("C", 75),
            new Grade("C-", 70),
            new Grade("D+", 67),
            new Grade("D", 65),
            new Grade("D-", 60),
            new Grade("F", 0)
        };

        for (Grade letterGrade : grades)
            System.out.println (letterGrade);
    }
}
public class Grade
{
    private String name;
    private int lowerBound;

    public Grade (String grade, int cutoff)
    {
        name = grade;
        lowerBound = cutoff;
    }

    public String toString()
    {
        return name + " \t " + lowerBound;
    }
}
continue

//-----------------------------------------------------------------
//  Name mutator.
//-----------------------------------------------------------------
public void setName (String grade)
{
    name = grade;
}

//-----------------------------------------------------------------
//  Lower bound mutator.
//-----------------------------------------------------------------
public void setLowerBound (int cutoff)
{
    lowerBound = cutoff;
}

continue
continue

// Name accessor.

public String getName()
{
    return name;
}

// Lower bound accessor.

public int getLowerBound()
{
    return lowerBound;
}
Arrays of Objects

• Now let's look at an example that manages a collection of DVD objects

• An initial capacity of 100 is created for the collection

• If more room is needed, a private method is used to create a larger array and transfer the current DVDs

• See Movies.java
• See DVDCollection.java
• See DVD.java
Arrays of Objects

- A UML diagram for the Movies program:
public class Movies
{
    // Creates a DVDCollection object and adds some DVDs to it. Prints
    // reports on the status of the collection.
    public static void main (String[] args)
    {
        DVDCollection movies = new DVDCollection();

        movies.addDVD ("The Godfather", "Francis Ford Coppala", 1972, 24.95, true);
        movies.addDVD ("District 9", "Neill Blomkamp", 2009, 19.95, false);
        movies.addDVD ("Iron Man", "Jon Favreau", 2008, 15.95, false);
        movies.addDVD ("All About Eve", "Joseph Mankiewicz", 1950, 17.50, false);
        movies.addDVD ("The Matrix", "Andy & Lana Wachowski", 1999, 19.95, true);

        System.out.println (movies);

        movies.addDVD ("Iron Man 2", "Jon Favreau", 2010, 22.99, false);
        movies.addDVD ("Casablanca", "Michael Curtiz", 1942, 19.95, false);

        System.out.println (movies);
    }
}
/**
 * Demonstrates the use of an array of objects.
 */

public class Movies {
    public static void main(String[] args) {
        DVDCollection movies = new DVDCollection();
        movies.addDVD("The Godfather", "Francis Ford Coppala", 1972, 24.95, true);
        movies.addDVD("District 9", "Neill Blomkamp", 2009, 19.95, false);
        movies.addDVD("Iron Man", "Jon Favreau", 2008, 15.95, false);
        movies.addDVD("All About Eve", "Joseph Mankiewicz", 1950, 17.50, false);
        movies.addDVD("The Matrix", "Andy & Lana Wachowski", 1999, 19.95, true);
        System.out.println(movies);
        movies.addDVD("Iron Man 2", "Jon Favreau", 2010, 22.99, false);
        movies.addDVD("Casablanca", "Michael Curtiz", 1942, 19.95, false);
        System.out.println(movies);
    }
}
public class Movies {

    // Creates a DVDCollection object and adds some DVDs to it. Prints reports on the status of the collection.
    public static void main(String[] args) {
        DVDCollection movies = new DVDCollection();
        movies.addDVD("The Godfather", "Francis Ford Coppala", 1972, 24.95, true);
        movies.addDVD("District 9", "Neill Blomkamp", 2009, 19.95, false);
        movies.addDVD("Iron Man", "Jon Favreau", 2008, 15.95, false);
        movies.addDVD("All About Eve", "Joseph Mankiewicz", 1950, 17.50, false);
        movies.addDVD("The Matrix", "Andy & Lana Wachowski", 1999, 19.95, true);
        System.out.println(movies);
        movies.addDVD("Iron Man 2", "Jon Favreau", 2010, 22.99, false);
        movies.addDVD("Casablanca", "Michael Curtiz", 1942, 19.95, false);
        System.out.println(movies);
    }
}

Output

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
My DVD Collection
Number of DVDs: 5
Total cost: $98.30
Average cost: $19.66
DVD List:
$24.95 1972  The Godfather  Francis Ford Coppala  Blu-Ray
$19.95 2009  District 9  Neill Blomkamp
$15.95 2008  Iron Man  Jon Favreau
$17.50 1950  All About Eve  Joseph Mankiewicz
$19.95 1999  The Matrix  Andy & Lana Wachowski  Blu-Ray

Output (continued)

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
My DVD Collection
Number of DVDs: 7
Total cost: $141.24
Average cost: $20.18
DVD List:
$24.95 1972  The Godfather  Francis Ford Coppala  Blu-Ray
$19.95 2009  District 9  Neill Blomkamp
$15.95 2008  Iron Man  Jon Favreau
$17.50 1950  All About Eve  Joseph Mankiewicz
$19.95 1999  The Matrix  Andy & Lana Wachowski  Blu-Ray
$22.99 2010  Iron Man 2  Jon Favreau
$19.95 1942  Casablanca  Michael Curtiz
import java.text.NumberFormat;

public class DVD {
    private String title, director;
    private int year;
    private double cost;
    private boolean bluRay;

    //-----------------------------------------------
    // Creates a new DVD with the specified information.
    //-----------------------------------------------
    public DVD (String title, String director, int year, double cost, boolean bluRay)
    {
        this.title = title;
        this.director = director;
        this.year = year;
        this.cost = cost;
        this.bluRay = bluRay;
    }
}
public String toString()  
{
    NumberFormat fmt = NumberFormat.getCurrencyInstance();

    String description;

    description = fmt.format(cost) + "\t" + year + "\t";
    description += title + "\t" + director;

    if (bluRay)
        description += "\t" + "Blu-Ray";

    return description;
}
import java.text.NumberFormat;

public class DVDCollection
{
    private DVD[] collection;
    private int count;
    private double totalCost;

    //-----------------------------------------------------------------
    // Constructor: Creates an initially empty collection.
    //-----------------------------------------------------------------
    public DVDCollection ()
    {
        collection = new DVD[100];
        count = 0;
        totalCost = 0.0;
    }

    continue
// Adds a DVD to the collection, increasing the size of the
// collection array if necessary.
public void addDVD (String title, String director, int year,
                   double cost, boolean bluRay)
{
    if (count == collection.length)
        increaseSize();

    collection[count] = new DVD (title, director, year, cost, bluRay);
    totalCost += cost;
    count++;
}

continue
public String toString()
{
    NumberFormat fmt = NumberFormat.getCurrencyInstance();

    String report = "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    My DVD Collection\n\n    Number of DVDs: {}
    Total cost: {}
    Average cost: {}

    DVD List:\n\n    "n\n    for (int dvd = 0; dvd < count; dvd++)
        report += collection[dvd].toString() + "\n"
    return report;
}

Can we implement this loop using a for each statement?
/**
 * Increases the capacity of the collection by creating a larger array and copying the existing collection into it.
 */

private void increaseSize ()
{
    DVD[] temp = new DVD[collection.length * 2];

    for (int dvd = 0; dvd < collection.length; dvd++)
        temp[dvd] = collection[dvd];

    collection = temp;
}
Quiz

- Suppose `team` is an array of strings meant to hold the names: Amanda, Clare, Emily, Julie, Katie, and Maria.
  - Write an array `declaration` for `team`

  - Show how to both `declare` and `populate` `team` using an initializer list.
Quiz

• Suppose team is an array of strings meant to hold the names: Amanda, Clare, Emily, Julie, Katie, and Maria.
  – Write an array declaration for team

  ```java
  String[] team = new String[6];
  ```

  – Show how to both declare and populate team using an initializer list.

  ```java
  String[] team = {"Amanda", "Clare", "Emily", "Julie", "Katie", "Maria"};
  ```
Quiz

Assume that BankAccount is a predefined class and that the declaration BankAccount[ ] firstEmpireBank; has already been performed. Then the following instruction reserves memory space for …

```java
    firstEmpireBank = new BankAccount[1000];
```

A) a reference variable to the memory that stores all 1000 BankAccount entries
B) 1000 reference variables, each of which point to a single BankAccount entry
C) a single BankAccount entry
D) 1000 BankAccount entries
E) 1000 reference variables and 1000 BankAccount entries
Quiz

Assume that BankAccount is a predefined class and that the declaration BankAccount[ ] firstEmpireBank; has already been performed. Then the following instruction reserves memory space for

```java
firstEmpireBank = new BankAccount[1000];
```

A) a reference variable to the memory that stores all 1000 BankAccount entries

B) 1000 reference variables, each of which point to a single BankAccount entry

C) a single BankAccount entry

D) 1000 BankAccount entries

E) 1000 reference variables and 1000 BankAccount entries
Command-Line Arguments

• The **signature** of the **main** method indicates that it takes an array of **String** objects as a parameter.

• These values come from **command-line arguments** that are provided when the interpreter is invoked.

• For example, the following invocation of the interpreter passes three **String** objects into the **main method** of the **StateEval** program:

```
java StateEval pennsylvania texas arizona
```

• See **NameTag.java**
public class NameTag
{
  public static void main (String[] args)
  {
    System.out.println ();
    System.out.println (args[0]);
    System.out.println ("My name is " + args[1]);
  }
}

public class NameTag {
    public static void main (String[] args) {
        System.out.println ();
        System.out.println ("     " + args[0]);
        System.out.println ("My name is " + args[1]);
    }
}

Command-Line Execution

> java NameTag Howdy John

Howdy
My name is John

> java NameTag Hello Bill

Hello
My name is Bill
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Mouse Events and Key Events
Variable Length Parameter Lists

• Suppose we wanted to create a method that processed a different amount of data from one invocation to the next

• For example, let's define a method called `average` that returns the average of a set of integer parameters

```java
// one call to average three values
mean1 = average (42, 69, 37);

// another call to average seven values
mean2 = average (35, 43, 93, 23, 40, 21, 75);
```
Variable Length Parameter Lists

• We could define **overloaded** versions of the **average method**
  – Downside: we'd need a separate version of the method for each additional parameter

• We could define the method to accept an **array of integers**
  – Downside: we'd have to create the array and store the integers prior to calling the method each time

• Instead, Java provides a convenient way to create **variable length parameter lists**
Variable Length Parameter Lists

• Using special syntax in the formal parameter list, we can define a method to accept **any number** of parameters **of the same type**

• For each call, the parameters are automatically put into an array for easy processing in the method

    public double average (int ... list) {
        // whatever
    }

Indicates a variable length parameter list

element type
array name
public double average (int ... list) {
    double result = 0.0;

    if (list.length != 0) {
        int sum = 0;
        for (int num : list)
            sum += num;
        result = (double)sum / list.length;
    }

    return result;
}
Variable Length Parameter Lists

• The type of the parameter can be any primitive or object type:

```java
public void printGrades (Grade ... grades)
{
    for (Grade letterGrade : grades)
        System.out.println (letterGrade);
}
```
Quick Check

Write method called `distance` that accepts a variable number of integers (which each represent the distance of one leg of a trip) and returns the total distance of the trip.
Quick Check

Write method called `distance` that accepts a variable number of integers (which each represent the distance of one leg of a trip) and returns the total distance of the trip.

```java
public int distance (int ... list){
    int sum = 0;
    if (list.length != 0)
        for (int num : list)
            sum = sum + num;
    return sum;
}
```
Variable Length Parameter Lists

• A method that accepts a variable number of parameters can also accept other parameters

• The following method accepts an int, a String object, and a variable number of double values into an array called nums

```java
public void test (int count, String name, double ... nums)
{
    // whatever
}
```
Variable Length Parameter Lists

• The varying number of parameters must come last in the formal arguments

• A method **cannot** accept **two** sets of varying parameters

• Constructors can also be set up to accept a variable number of parameters

• See `VariableParameters.java`
• See `Family.java`
public class VariableParameters
{
    public static void main (String[] args)
    {
        Family lewis = new Family ("John", "Sharon", "Justin", "Kayla", "Nathan", "Samantha");


        System.out.println(lewis);
        System.out.println();
        System.out.println(camden);
    }
}
public class VariableParameters {
    public static void main (String[] args) {
        Family lewis = new Family("John", "Sharon", "Justin", "Kayla", "Nathan", "Samantha");
        System.out.println(lewis);
        System.out.println();
        System.out.println(camden);
    }
}
public class Family
{
    private String[] members;

    public Family (String ... names)
    {
        members = names;
    }

    continue
public String toString() {
    String result = "";

    for (String name : members) {
        result += name + "\n";
    }

    return result;
}
Two-Dimensional Arrays

- A *one-dimensional array* stores a list of elements
- A *two-dimensional array* can be thought of as a table of elements, with rows and columns
Two-Dimensional Arrays

• To be precise, in Java a two-dimensional array is an array of arrays

• A two-dimensional array is declared by specifying the size of each dimension separately:

```java
int[][] table = new int[12][50];
```

• A array element is referenced using two index values:

```java
value = table[3][6]
```

• The array stored in one row can be specified using one index (table[0] is the first row array)
## Two-Dimensional Arrays

<table>
<thead>
<tr>
<th>Expression</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>table</td>
<td>int[][]</td>
<td>2D array of integers, or array of integer arrays</td>
</tr>
<tr>
<td>table[5]</td>
<td>int[]</td>
<td>array of integers</td>
</tr>
<tr>
<td>table[5][12]</td>
<td>int</td>
<td>integer</td>
</tr>
</tbody>
</table>

- See TwoDArray.java
- See SodaSurvey.java
public class TwoDArray
{
    //-----------------------------------
    //  Creates a 2D array of integers, fills it with increasing
    //  integer values, then prints them out.
    //-----------------------------------
    public static void main (String[] args)
    {
        int[][] table = new int[5][10];

        // Load the table with values
        for (int row=0; row < table.length; row++)
            for (int col=0; col < table[row].length; col++)
                table[row][col] = row * 10 + col;

        // Print the table
        for (int row=0; row < table.length; row++)
            { for (int col=0; col < table[row].length; col++)
                System.out.print (table[row][col] + "\t");
                System.out.println();
            }
    }
}
public static void main (String[] args)
{
    int[][] table = new int[5][10];

    // Load the table with values
    for (int row=0; row < table.length; row++)
        for (int col=0; col < table[row].length; col++)
            table[row][col] = row * 10 + col;

    // Print the table
    for (int row=0; row < table.length; row++)
    {
        for (int col=0; col < table[row].length; col++)
            System.out.print (table[row][col] + "\t");
        System.out.println();
    }
}
import java.text.DecimalFormat;

public class SodaSurvey
{
    // Determines and prints the average of each row (soda) and each column (respondent) of the survey scores.
    public static void main (String[] args)
    {
        int[][] scores = {{3, 4, 5, 2, 1, 4, 3, 2, 4, 4},
                          {2, 4, 3, 4, 3, 3, 2, 1, 2, 2},
                          {3, 5, 4, 5, 5, 3, 2, 5, 5, 5},
                          {1, 1, 1, 3, 1, 2, 1, 3, 2, 4}};

        final int SODAS = scores.length;
        final int PEOPLE = scores[0].length;

        int[] sodaSum = new int[SODAS];
        int[] personSum = new int[PEOPLE];
```java
for (int soda=0; soda < SODAS; soda++)
    for (int person=0; person < PEOPLE; person++)
    {
        sodaSum[soda] += scores[soda][person];
        personSum[person] += scores[soda][person];
    }

DecimalFormat fmt = new DecimalFormat("0.#");
System.out.println("Averages:\n");

for (int soda=0; soda < SODAS; soda++)
    System.out.println("Soda #" + (soda+1) + ": " +
            fmt.format((float)sodaSum[soda]/PEOPLE));

System.out.println();
for (int person=0; person < PEOPLE; person++)
    System.out.println("Person #" + (person+1) + ": " +
            fmt.format((float)personSum[person]/SODAS));
```
Averages:

Soda #1: 3.2
Soda #2: 2.6
Soda #3: 4.2
Soda #4: 1.9

Person #1: 2.2
Person #2: 3.5
Person #3: 3.2
Person #4: 3.5
Person #5: 2.5
Person #6: 3
Person #7: 2
Person #8: 2.8
Person #9: 3.2
Person #10: 3.8
Multidimensional Arrays

- An array can have many dimensions – if it has more than one dimension, it is called a multidimensional array

- Each dimension subdivides the previous one into the specified number of elements

- Each dimension has its own length constant

- Because each dimension is an array of array references, the arrays within one dimension can be of different lengths
  - these are sometimes called ragged arrays

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Quiz

• The trace of an nxm bidimensional matrix $A$, with entries $a_{ij}$ is defined as:

$$trace(A) = \sum_{i=1}^{\min(n,m)} a_{ii}$$

• Implement a static method of the class ArrayUtil that computes the trace of a matrix
public static int trace(int[][] m) {
    int res = 0;
    int min = Math.min(m.length, m[0].length);
    for (int i = 0; i < min; i++) {
        res += m[i][i];
    }
    return res;
}
Arrays class

• Provides a number of useful **static** methods for manipulating arrays
  
  – **asList**(*T ... a*) : returns a List<T> object containing the input objects. For example:
    
    ```java
    List<String> stooges = Arrays.asList("Larry", "Moe", "Curly");
    ```

  – **binarySearch**(*int[] a, int key*) : searches the specified array of ints for the specified value. Returns index of the search key, if it is contained in the array (otherwise a negative value)

  – **copyOf**(*long[] original, int newLength*) : returns a copy the specified array, truncating or padding with zeros (if necessary) so the copy has the specified length
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Mouse Events and Key Events
Polygons and Polylines

• Arrays can be helpful in graphics processing

• For example, they can be used to store a list of coordinates

• A *polygon* is a multisided, closed shape

• A *polyline* is similar to a polygon except that its endpoints do not meet, and it cannot be filled

• See `Rocket.java`
• See `RocketPanel.java`
import javax.swing.JFrame;

public class Rocket
{
    //  Creates the main frame of the program.
    public static void main (String[] args)
    {
        JFrame frame = new JFrame ("Rocket");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);

        RocketPanel panel = new RocketPanel();

        frame.getContentPane().add(panel);
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class Rocket {
    // Creates the main frame of the program.
    public static void main (String[] args)
    {
        JFrame frame = new JFrame("Rocket");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

        RocketPanel panel = new RocketPanel();

        frame.getContentPane().add(panel);
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JPanel;
import java.awt.*;

public class RocketPanel extends JPanel {

private int[] xRocket = {100, 120, 120, 130, 130, 70, 70, 80, 80};
private int[] yRocket = {15, 40, 115, 125, 150, 150, 125, 115, 40};

private int[] xWindow = {95, 105, 110, 90};
private int[] yWindow = {45, 45, 70, 70};

private int[] xFlame = {70, 70, 75, 80, 90, 100, 110, 115, 120, 130, 130};
private int[] yFlame = {155, 170, 165, 190, 170, 175, 160, 185, 160, 175, 155};
}
public RocketPanel()
{
    setBackground (Color.black);
    setPreferredSize (new Dimension(200, 200));
}

public void paintComponent (Graphics page)
{
    super.paintComponent (page);

    page.setColor (Color.cyan);
    page.fillPolygon (xRocket, yRocket, xRocket.length);

    page.setColor (Color.gray);
    page.fillPolygon (xWindow, yWindow, xWindow.length);

    page.setColor (Color.red);
    page.drawPolyline (xFlame, yFlame, xFlame.length);
}
The Polygon Class

• The `Polygon` class can also be used to define and draw a polygon

• It is part of the `java.awt` package

• Versions of the overloaded `drawPolygon` and `fillPolygon` methods (of the `Graphics` class) take a single `Polygon` object as a parameter instead of arrays of coordinates
# Mouse Events

- Events related to the mouse are separated into *mouse events* and *mouse motion events*

- **Mouse Events:**

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>mouse pressed</em></td>
<td>the mouse button is pressed down</td>
</tr>
<tr>
<td><em>mouse released</em></td>
<td>the mouse button is released</td>
</tr>
<tr>
<td><em>mouse clicked</em></td>
<td>the mouse button is pressed down and released without moving the mouse in between</td>
</tr>
<tr>
<td><em>mouse entered</em></td>
<td>the mouse pointer is moved onto (over) a component</td>
</tr>
<tr>
<td><em>mouse exited</em></td>
<td>the mouse pointer is moved off of a component</td>
</tr>
</tbody>
</table>
Mouse Events

- Mouse **motion events**:

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mouse moved</td>
<td>the mouse is moved</td>
</tr>
<tr>
<td>mouse dragged</td>
<td>the mouse is moved while the mouse button is pressed down</td>
</tr>
</tbody>
</table>

- Listeners for mouse events are created using the `MouseListener` and `MouseMotionListener` interfaces.

- A `MouseEvent` object is passed to the appropriate method when a mouse event occurs.
Mouse Events

• For a given program, we may only care about one or two mouse events

• To *satisfy the implementation* of a listener interface, *empty* methods must be provided for unused events

• See `Dots.java`
• See `DotsPanel.java`
import javax.swing.JFrame;

public class Dots {
    // Creates and displays the application frame.
    public static void main (String[] args) {
        JFrame frame = new JFrame ("Dots");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add (new DotsPanel());
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class Dots {
    public static void main(String[] args) {
        JFrame frame = new JFrame("Dots");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add(new DotsPanel());
        frame.pack();
        frame.setVisible(true);
    }
}
public class DotsPanel extends JPanel {
    private final int SIZE = 6; // radius of each dot

    private ArrayList<Point> pointList;

    continue
// Constructor: Sets up this panel to listen for mouse events.
public DotsPanel()
{
    pointList = new ArrayList<Point>();

    addMouseListener (new DotsListener());
    setBackground (Color.black);
    setPreferredSize (new Dimension(300, 200));
}

// Draws all of the dots stored in the list.
public void paintComponent (Graphics page)
{
    super.paintComponent(page);
    page.setColor (Color.green);

    for (Point spot : pointList)
        page.fillOval (spot.x-SIZE, spot.y-SIZE, SIZE*2, SIZE*2);

    page.drawString ("Count: " + pointList.size(), 5, 15);
}
private class DotsListener implements MouseListener
{
    // Adds the current point to the list of points and redraws
    // the panel whenever the mouse button is pressed.
    public void mousePressed (MouseEvent event)
    {
        pointList.add(event.getPoint());
        repaint();
    }
    
    // Provide empty definitions for unused event methods.
    public void mouseClicked (MouseEvent event) {} 
    public void mouseReleased (MouseEvent event) {}
    public void mouseEntered (MouseEvent event) {}
    public void mouseExited (MouseEvent event) {}
}
Mouse Events

- *Rubberbanding* is the visual effect in which a shape is "stretched" as it is drawn using the mouse.

- The following example continually redraws a line as the mouse is dragged.

- See `RubberLines.java`
- See `RubberLinesPanel.java`
import javax.swing.JFrame;

public class RubberLines
{
    public static void main (String[] args)
    {
        JFrame frame = new JFrame("Rubber Lines");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

        frame.getContentPane().add(new RubberLinesPanel());

        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class RubberLines
{
    public static void main(String[] args)
    {
        JFrame frame = new JFrame("Rubber Lines");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

        frame.getContentPane().add(new RubberLinesPanel());

        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JPanel;
import java.awt.*;
import java.awt.event.*;

public class RubberLinesPanel extends JPanel {
    private Point point1 = null, point2 = null;

    // Constructor: Sets up this panel to listen for mouse events.
    public RubberLinesPanel()
    {
        LineListener listener = new LineListener();
        addMouseListener (listener);
        addMouseMotionListener (listener);
        setBackground (Color.black);
        setPreferredSize (new Dimension(400, 200));
    }
}

continue
continue

// Draw the current line from the initial mouse-pressed point to
// the current position of the mouse.

public void paintComponent (Graphics page)
{
    super.paintComponent (page);
    page.setColor (Color.yellow);
    if (point1 != null && point2 != null)
        page.drawLine (point1.x, point1.y, point2.x, point2.y);
}

//*****************************************************************
// Represents the listener for all mouse events.
//*****************************************************************

private class LineListener implements MouseListener, MouseMotionListener
{
    // Captures the initial position at which the mouse button is
    // pressed.

    public void mousePressed (MouseEvent event)
    {
        point1 = event.getPoint();
    }
}
public void mouseDragged (MouseEvent event)
{
    point2 = event.getPoint();
    repaint();
}

public void mouseClicked (MouseEvent event) {} 
public void mouseReleased (MouseEvent event) {} 
public void mouseEntered (MouseEvent event) {} 
public void mouseExited (MouseEvent event) {} 
public void mouseMoved (MouseEvent event) {}
Key Events

- A *key event* is generated when the user types on the keyboard

<table>
<thead>
<tr>
<th>key pressed</th>
<th>a key on the keyboard is pressed down</th>
</tr>
</thead>
<tbody>
<tr>
<td>key released</td>
<td>a key on the keyboard is released</td>
</tr>
<tr>
<td>key typed</td>
<td>a key on the keyboard is pressed down and released</td>
</tr>
</tbody>
</table>

- Listeners for key events are created by implementing the `KeyListener` interface

- A `KeyEvent` object is passed to the appropriate method when a key event occurs
Key Events

• The component that generates a key event is the one that has the current *keyboard focus*

• Constants in the `KeyEvent` class can be used to determine which key was pressed

• The following example "moves" an image of an arrow as the user types the keyboard arrow keys

• See `Direction.java`
• See `DirectionPanel.java`
// Demonstrates key events.

import javax.swing.JFrame;

public class Direction
{

    // Creates and displays the application frame.
    public static void main (String[] args)
    {
        JFrame frame = new JFrame("Direction");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add(new DirectionPanel());
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class Direction {
    public static void main(String[] args) {
        JFrame frame = new JFrame("Direction");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add(new DirectionPanel());
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class DirectionPanel extends JPanel {
    private final int WIDTH = 300, HEIGHT = 200;
    private final int JUMP = 10; // increment for image movement

    private final int IMAGE_SIZE = 31;

    private ImageIcon up, down, right, left, currentImage;
    private int x, y;
```java
public DirectionPanel()
{
    addKeyListener (new DirectionListener());

    x = WIDTH / 2;
    y = HEIGHT / 2;

    up = new ImageIcon ("arrowUp.gif");
    down = new ImageIcon ("arrowDown.gif");
    left = new ImageIcon ("arrowLeft.gif");
    right = new ImageIcon ("arrowRight.gif");

    currentImage = right;

    setBackground (Color.black);
    setPreferredSize (new Dimension(WIDTH, HEIGHT));
    setFocusable(true);
}
```
continue

//---Draws the image in the current location.
//---

public void paintComponent (Graphics page)
{
    super.paintComponent (page);
    currentImage.paintIcon (this, page, x, y);
}

//*****************************************************************
// Represents the listener for keyboard activity.
//*****************************************************************
private class DirectionListener implements KeyListener
{
    //---
    // Responds to the user pressing arrow keys by adjusting the
    // image and image location accordingly.
    //---

    public void keyPressed (KeyEvent event)
    {
        switch (event.getKeyCode())
        {
            case KeyEvent.VK_UP:
                currentImage = up;
                y -= JUMP;
                break;
        }
    }
}
continue

case KeyEvent.VK_DOWN:
    currentImage = down;
    y += JUMP;
    break;

case KeyEvent.VK_LEFT:
    currentImage = left;
    x -= JUMP;
    break;

case KeyEvent.VK_RIGHT:
    currentImage = right;
    x += JUMP;
    break;

}
Summary

• Chapter 8 has focused on:
  – array declaration and use
  – bounds checking and capacity
  – arrays that store object references
  – variable length parameter lists
  – multidimensional arrays
  – polygons and polylines
  – mouse events and keyboard events
Quiz

Given the following method:

```java
public void differentArray(float[] x)
{
    x = new float[100];
    x[0] = 26.9f;
}
```

what is the output after the following code is run?

```java
float[] xx = new float[100];
xx[0] = 55.8f;
differentArray(xx);
System.out.println("xx[0] = " + xx[0]);
```
Quiz

Given the following method:

```java
public void differentArray(float[] x)
{
    x = new float[100];
    x[0] = 26.9f;
}
```

what is the output after the following code is run?

```java
float[] xx = new float[100];
xx[0] = 55.8f;
differentArray(xx);
System.out.println("xx[0] = " + xx[0]);
```

```
x[0] = 55.8
```
public static void tryString(String s) {
    s = "a different string";
}

When the following code is executed, what does the print statement produce?

String str = "This is a string literal.";
tryString(str);
System.out.println("str = " + str);
Quiz

public static void tryString(String s)
{
    s = "a different string";
}

When the following code is executed, what does the print statement produce?

String str = "This is a string literal.";
tryString(str);
System.out.println("str = " + str);

str = This is a string literal.