Arrays

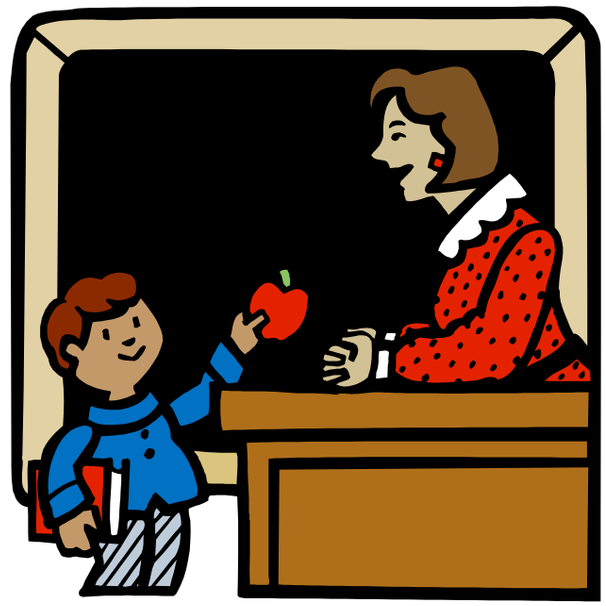
Chapter 9

Contents

Chapter Objectives

- Investigate Java one-dimensional arrays
- Study sorting and searching of lists
- Implement command-line arguments
- Introduce two-dimensional arrays
- Build a matrix class
- Show use of arrays in graphical programming
- Describe use of matrix methods for solving linear systems

Example: Ms. White's Test Score Analyzer



Problem:

Ms. White needs to analyze students' test performance. She needs a program to display a name and let her enter the test score. Then it should compute and display the average. Finally it should give a report with names, scores, and deviation from the average.

Behavior

```
Test Analysis -- enter scores:
Aardvark, James        : 92
Biffkirk, Sue          : 79
Crouse, Nancy          : 95
. . .
Average = 87.39

Summary . . .
```

- Display the name in a prompt
- Read the score
- Compute average
- Print summary, including deviation from mean

Objects

Object	Kind	Type	Name
sequence of names	constant	`String[]`	`STUDENTS`
each name	varying	`String`	`STUDENTS[i]`
sequence of scores	varying	`double[]`	`scores`
each score	varying	`double`	`scores[i]`
the screen	varying	`Screen`	`theScreen`
prompt for each score	varying	`String`	
average	varying	`double`	`average`

Algorithm

1. Define **`STUDENTS`** array to hold names, array **`scores`** to hold test scores
2. For each student in array
   a) display name & prompt
   b) read double, store in array scores
3. Compute **`average`**, display it
4. For each student in array
   a) Display name, test score, difference between that score and **`average`**

Coding and Testing

- Note source code, Figure 9.1
- Features:
  - array of student names initialized at declaration
  - use of `NUMBER_OF_STUDENTS` constant
  - for loops to process the arrays

9.2 Arrays

- Java arrays are objects
  - must be accessed via handles
- Defining an array

  `Type [] name`

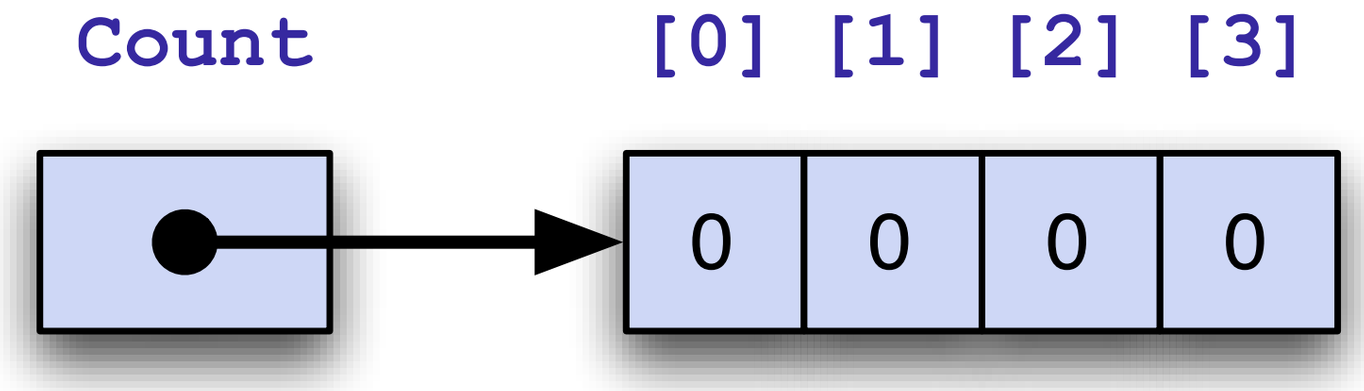
  - This declares the handle only
  - Initialized to null
  - Stores an address when arrays are created
- Where:
  - **`Type`** specifies the kind of values the array stores
  - the brackets **`[ ]`** indicate this is an array
  - **`name`** is the handle to access the array

Definitions Using Array Literals

- Used when exact size and initial values of an array are known in advance
  - used to initialize the array handle

```
int [] count = { 0,0,0,0}
```

Visualize the results of the above command

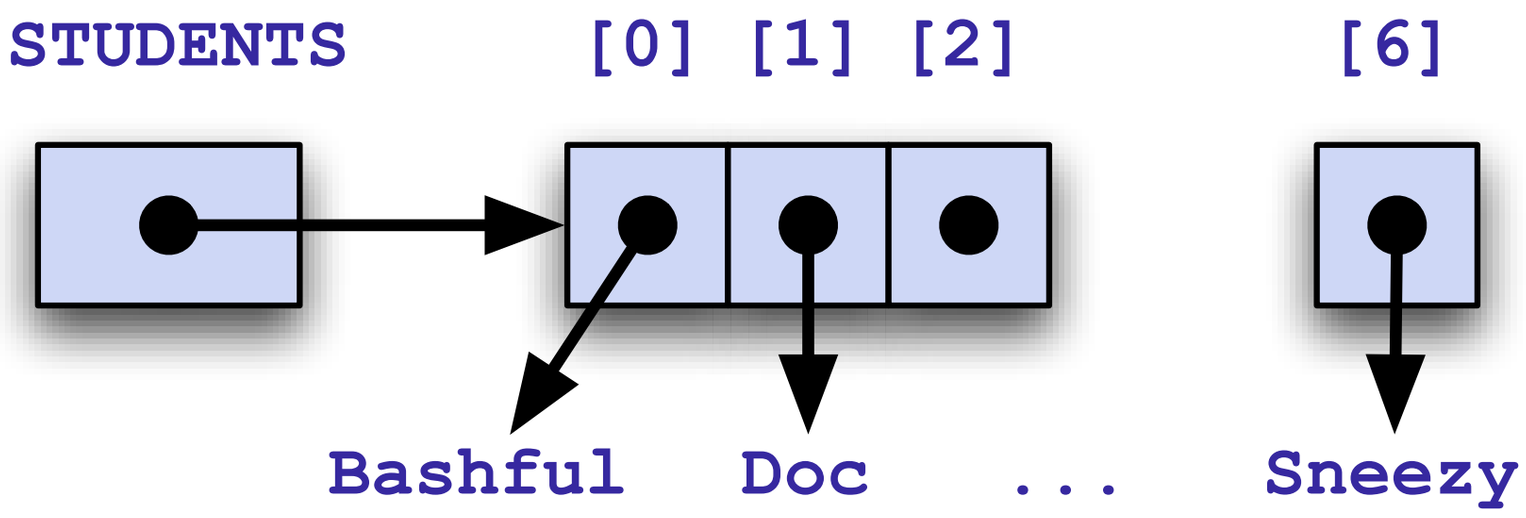


Definitions Using Array Literals

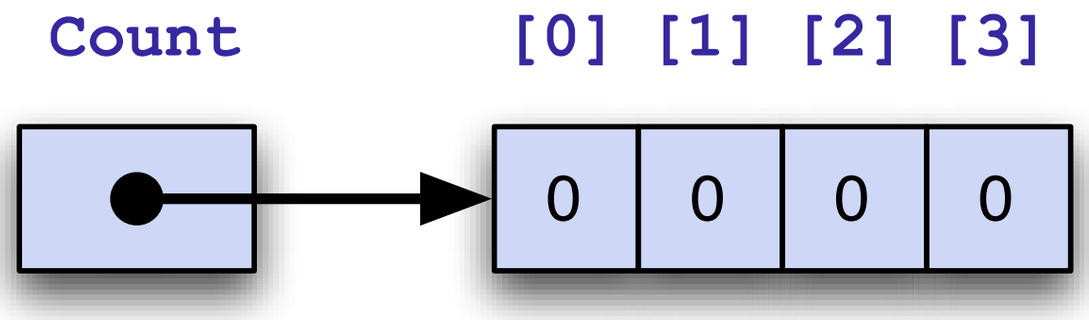
- Consider student names in Section 9.1

```
final String[] STUDENTS = {
"Bashful", "Doc", ..., "Sneezy"
};
```

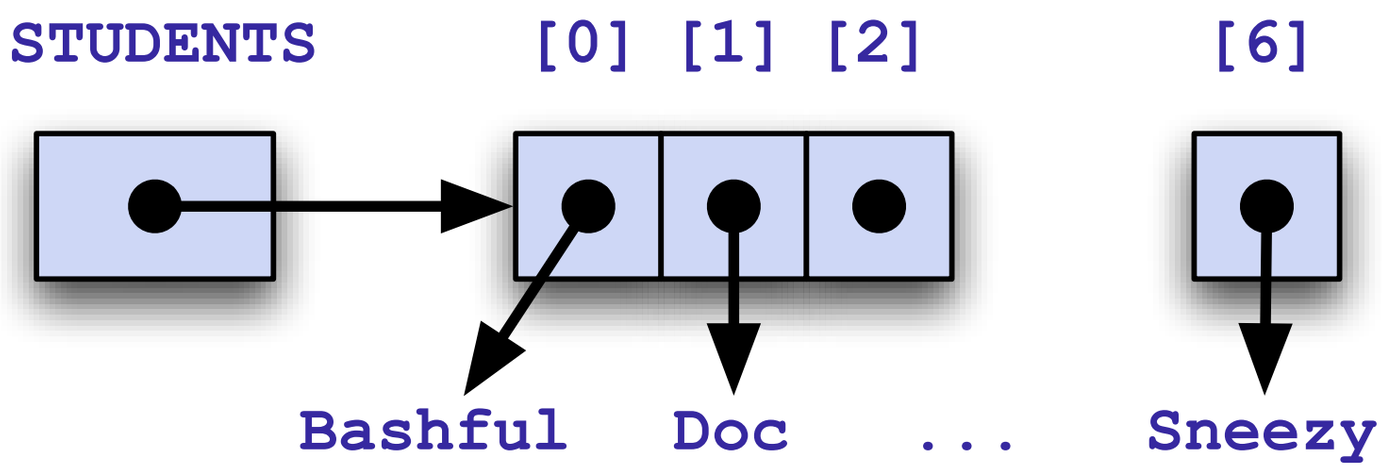
- Note results:



Contrast Definitions



Elements are primitive values (0s in this case)



Elements are handles for Strings

Definitions using `new`

```
double [] scores = new double
[NUMBER_OF_STUDENTS];
```

- The above statement will:
  - allocate block of memory to hold 7 `doubles`
  - initialize block with zeros
  - returns the address of the block
  - create a handle called `scores`
  - store address of the block in `scores`

Syntax

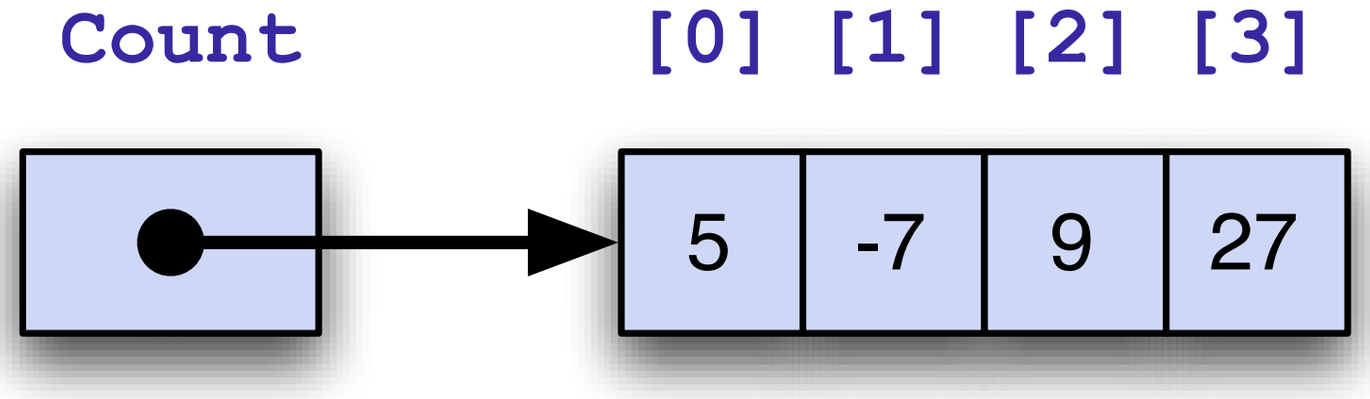
- Forms

```
ElementType [] arrayName;
ElementType [] arrayName =
   new ElementType [size];
ElementType [] arrayName =
   array-literal;
```

- Where:
  - `ElementType` is any type
  - `arrayName` is the handle for the array
  - `array-literal` is a list of literals enclosed in curly braces `{ }`

Processing Array Elements

- Access individual elements of an array using:
  - the name (handle) of the array
  - a number (index or subscript) that tells which of the element of the array



- What value is stored in `count[2]`?

Processing Array Elements

- Often a `for( )` loop is used to process each of the elements of the array in turn.

```
for (int i = 0; i < NUM_STUDENTS; i++)
{  theScreen.print( STUDENTS[i] +
                   "\t"+scores[i]+"\t" );
 theScreen.println(scores[i]-average);
}
```

- The loop control variable, `i`, is used as the index to access array components

Array Parameters

- Methods can accept arrays via parameters
- Use square brackets `[ ]` in the parameter declaration:

```
public static double sum
                (double [] array)
{ for (int i=0; i < array.length; i++)
    . . . }
```

- This works for any size array
  - use the `.length` attribute of an array to control the for loop

Methods that Return Array Values

- A method may return an array as its result

Declare return type

Declare local array for receiving input

```
public static double[] readArray()
  { . . . // ask for now many, n
    double result[] = new double[n];
    for (i = 0; i < n; i++) {
       theScreen.print("Enter …");
       result[i] = theKeyboard.readDouble();
    }
    return result;
  }
```

Local array is returned

The Assignment Operation

- Java provides a few operations to use with arrays, including assignment
- Consider:

```
int [] alist = { 11, 12, 13, 14};
int [] blist;
blist = alist;
```

- Recall that `alist` and `blist` are handles
  - `alist` contains an address of where the numbers are
  - `blist` now contains that same address
  - `blist` does not have a copy of `alist`

Array Cloning

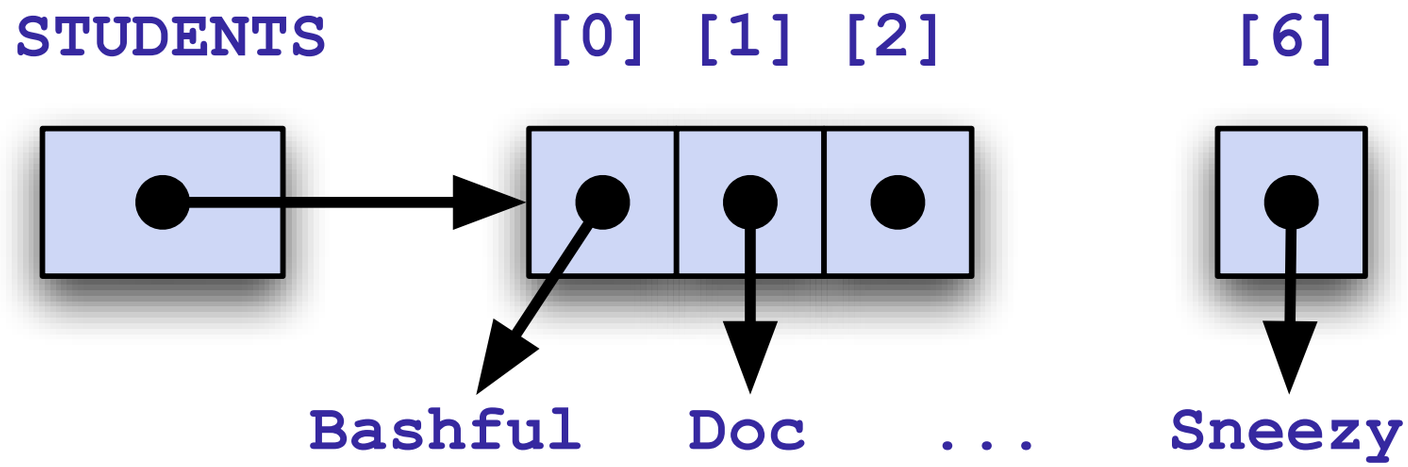
- To actually create another array with its own values, Java provides the `.clone()` method

```
int [] alist = { 11, 12, 13, 14};
int [] blist;
blist = alist.clone();
```

- Now there are two separate lists of numbers, one with handle **`alist`**, the other with handle **`blist`**

Array Cloning with Reference Types

- Recall previous declaration:



Elements are handles for `String` values

Called a "shallow copy" operation

- Consider:
  `String[] s_list = STUDENTS.clone();`
- This will create another list of handles, also pointing to the names

Array Cloning with Reference Types

- We can write our own “deep copy” method

```
public String[] deepCopy
                (String [] original)
{ String [] result =
        new String(original.length);
for (i = 0; i < original.length; i++)
 result[i] = original[i].clone();
return result;
}
```

Array Equality

- Java has an `equals()` method for classes
  `if (a1.equals(a2)) …`
- If `a1` and `a2` are arrays, the `equals()` method just looks at the addresses the handles point to
- They could be pointing to different addresses but the contents of the array still be equal
  - It is the contents that we really wish to compare

Array Equality

- We must write our own method to compare the arrays
  - they both must have the same length
  - then use a `for( )` loop to compare element by element for equality

```
if (list1.length==list2.length)
{ for (int i = 0; i<list1.length; i++)
    if (list1[i] != list2[i])
      return false;
    return true;
} else
    return false;
```

Method returns as soon as one pair is not equal

The `Vector` Class

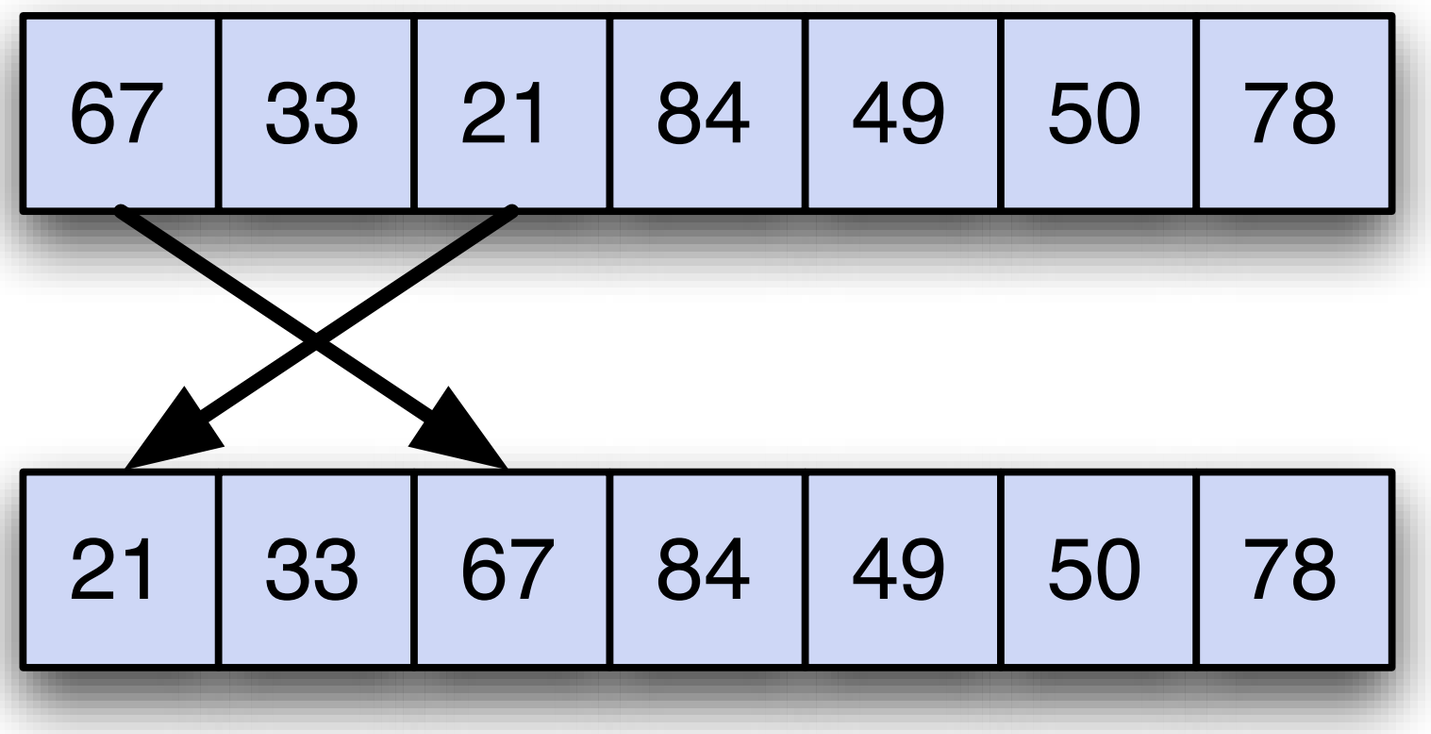
- Arrays are fixed in size at declaration time
  - cannot grow or shrink dynamically during run time
- Java provides a `Vector` class which can grow or shrink during the run of the program
- Note methods provided, Table 9.1 from text

9.3 Sorting

- Arranging items in a list so they are in either ascending or descending order
- There are several algorithms to accomplish this – some are known as:
  - selection sort
  - linear insertion sort
  - quicksort

Selection Sort

- Make passes through the list (or part of it)
  - on each pass select one item (smallest or largest) to be correctly position
  - exchange that item with the one that was in its place



Selection Sort

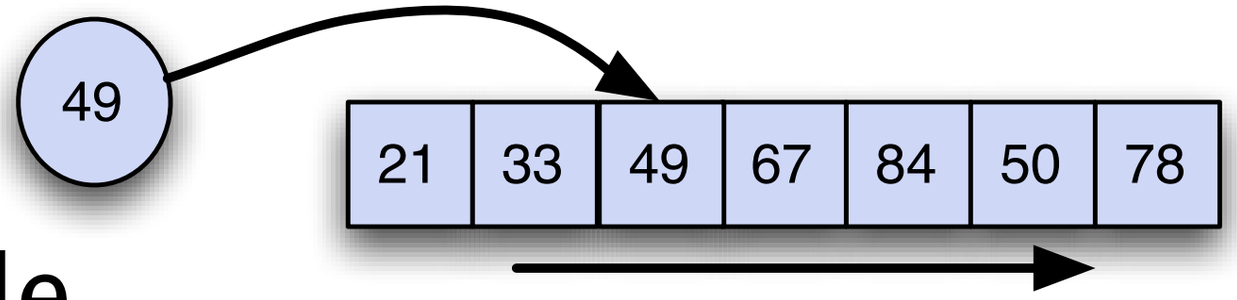
- On successive passes
  - must only check beyond where smallest item has been placed

67	33	21	84	49	50	78

- A pair of nested `for()` loops will accomplish this checking and swapping of values
- Note: this is a simple but inefficient algorithm

Linear Insertion Sort

- As list is built, keep it sorted
  - place new values in the list where they belong



- Tasks include
  - finding where the new item belongs
  - shifting all elements from that slot and beyond over one slot
  - inserting the new item in the vacated spot
- Again, a double nested loop can accomplish this task
- This is efficient for small lists

Quicksort

- Very efficient
- Implemented by a recursive algorithm
- Strategy
  - choose a pivot point
  - perform exchanges so all elements to the left are less than the pivot
  - all elements on the right are greater
  - this makes 2 sub lists where the same strategy with the pivot can be performed (repeatedly)
  - this is a "divide and conquer" concept

9.4 Searching

- Linear search
  - begin with first item in a list
  - search sequentially until desired item found or reach end of list
- Binary search (of a sorted list)
  - look at middle element
    - if target value found, done
  - if target value is higher, look in middle of top half of list
  - if target value is lower, look in middle of lower half of list

Contrast Search Algorithms

- Linear search
  - with n items in the list, may require n comparisons to find target
- Binary search
  - with n items in the list, requires at most $\log_2 n$ comparisons
  - for example with 1024 items, maximum of 10 comparisons
- Conclusion: Binary search is more efficient

9.5 Processing Command-Line Arguments

- Recall the heading for the method `main()`

```
public static void main(String[] args)
 { . . . }
```

  - From this chapter we know that `args` is a handle for an array of `String` values
  - These string values can be used in the program

Command-Line Environments and Arguments

- In UNIX and MS-DOS the user types in commands at the prompt

```
C:\> mkdir mydocs
```

- **`mkdir`** is a program
  - **`mydocs`** is the <u>argument</u> sent to the program
- This is where we can use **`args`**

Running Java from the Command Line

- At the command line enter:
  `java ClassName`
- The java interpreter is called
  - **`ClassName`** is an argument for that program
- It would also be possible to enter

`java ClassName` $\texttt{argmt}_1$ $\texttt{argmt}_2$ … $\texttt{argmt}_n$

- The interpreter builds a **`String`** array of n elements for **`ClassName`**
  - **`arg[i]`** is the handle for $\texttt{argmnt}_i$

Using Command-Line Arguments

- Consider source code that would list the command line arguments received by a program:

```
System.out.println( "There are " +
   args.length+" arguments");
for (int i =0; i < args.length; i++)
   System.out.println(args[i]);
```

Example: Square Root Calculator

- The program will be run from the command-line
- Given a real value (or values) it will print the square root for all values received as command-line arguments

```
java Sqrt 4 25 2
2
5
1.414
```

Objects

Object	Kind	Type	Name
sequence of arguments	variable	`String[]`	`args`
number of arguments	variable	`int`	`args.length`
particular argument	variable	`double`	`inValue`
square root of the argument	variable	`double`	

Algorithm

1. If `args.length < 1`, display error message, quit
2. For each integer `i`, 0 to `args.length - 1` …
   a) change the `String` value, `arg[i]`, to a double, `inValue`
   b) display `inValue` and its square root

Note source code Figure 9.3 in text

9.4 Multidimensional Arrays

- Arrays studied so far have one dimension … length
- It is also possible to define arrays with more than one dimension
- Two dimensional arrays can store values arranged in rows and columns
- Three dimensional arrays can store values arranged in rows, columns, and ranks (or pages)

Sample Problem:

- Consider a trucking business with centers in 6 cities. The owner requires a computerized mileage chart for the drivers
- Given any of the two cities, the program must display the approximate mileage between them

Program Behavior

- Display a numbered menu of cities
- Read the numbers of two cities from keyboard
- Look up mileage between the cities in a two dimensional table of values
- Display the mileage

Objects

Objects	Kind	Type	Name
menu of cities	constant	`String`	`CITY_MENU`
number of 1st city	varying	`int`	`city1`
number of 2nd city	varying	`int`	`city2`
mileage chart	constant	`int[][]`	`MILEAGE_CHART`
the mileage	varying	`int`	`mileage`

Algorithm

- Define
  - `MILEAGE_CHART` (2D array)
  - `CITY_MENU` (list of supported cities)
- Display `CITY_MENU`
- Read two integers from keyboard into `city1` and `city2`
- Calculate `mileage` by looking up `MILEAGE_CHART[city1][city2]`
- Display `mileage`

Coding and Testing

- Note source code, Figure 9.4
  - accompanying sample run
- Note definition and initialization of **MILEAGE_CHART**

```
final int [][] MILEAGE_CHART
 = { { 0, 97 … 130 },      // Daytona
     { 97,     …  128},
       . . .
     { 130 …         0} };  // Tampa
```

Accessing 2D Array Elements

- Requires two indices
- Which cell is `MILEAGE_CHART [3][2]`?

Row

Column

	[0]	[1]	[2]	[3]	[4]	[5]
[0]	0	97	90	268	262	130
[1]	97	0	74	337	144	128
[2]	90	74	0	354	174	201
[3]	268	337	354	0	475	269
[4]	262	144	174	475	0	238
[5]	130	128	201	269	238	0

Defining 2D Array Operations

- As with 1D arrays, variables and constants are handles to array objects
- Take care with assignment operator
  - use `clone()` method for shallow copy
  - write our own method for deep copy
- Recall that `equals()` compares handles of the 2D arrays
  - we must define our own `equals()` method for comparing individual values

Matrix Class

- A two-dimensional array with m rows and n columns is called an m x n matrix
- Mathematicians perform a variety of operations
  - matrix multiplication
  - matrix addition, subtraction

Matrix Multiplication Algorithm

1. If no. columns in **`mat1`** ≠ no. rows in **`mat2`**, product not defined, terminate
2. For each row **`i`** in **`mat1`**
   For each column **`j`** in **`mat2`**
   a) set **`sum`** = 0
   b) for each column **`k`** in **`mat1`** add **`mat1[i][k]*mat2[k][j]`** to **`sum`**
   c) set **`mat3[i][j]`** equal to **`sum`**

Building a `Matrix` Class

- Operations needed
- Default constructor, initialize empty
- Explicit value constructor, specify size
- Input: fill with values from keyboard
- Output: convert to `String` representation
- Retrieve element at `[r][c]`
- Change value at `[r][c]`
- Return product of this matrix with another

Declaration of Class

```
public class Matrix {
public Matrix() { } // stub for constructor
public Matrix (int rows, int columns) { }
 // explicit constructor
  . . .
public Matrix times (Matrix mat2) { }
 // multiply method


private int  myRows;
private int  myColumns
private double [ ] [ ] myArray;
}
```

Default Constructor

```
public Matrix()
{
    myArray = null;
    myRows = 0;
    myColumns = 0;
}
```

- Usage:

```
Matrix m = new Matrix();
```

Explicit-Value Constructor

```
public Matrix(int rows, int columns)
{
   if (rows < 0 || columns < 0)
      …// error message
   else
   { myArray = new double;
      [rows][columns];
      myRows = rows;
      myColumns = columns;
   }
}
```

- Usage:

```
Matrix m = new Matrix (7,12);
```

Other Methods

- Matrix Output, `toString()`, Figure 9.7
- Matrix Input, `read()`, Figure 9.8
- Attribute Accessors, Figure 9.9
  - return `myRows`
  - return `myColumns`
- Individual element
  - accessor, mutator Figure 9.10
- Multiplication method Figure 9.11

Array Declaration Syntax

- Form

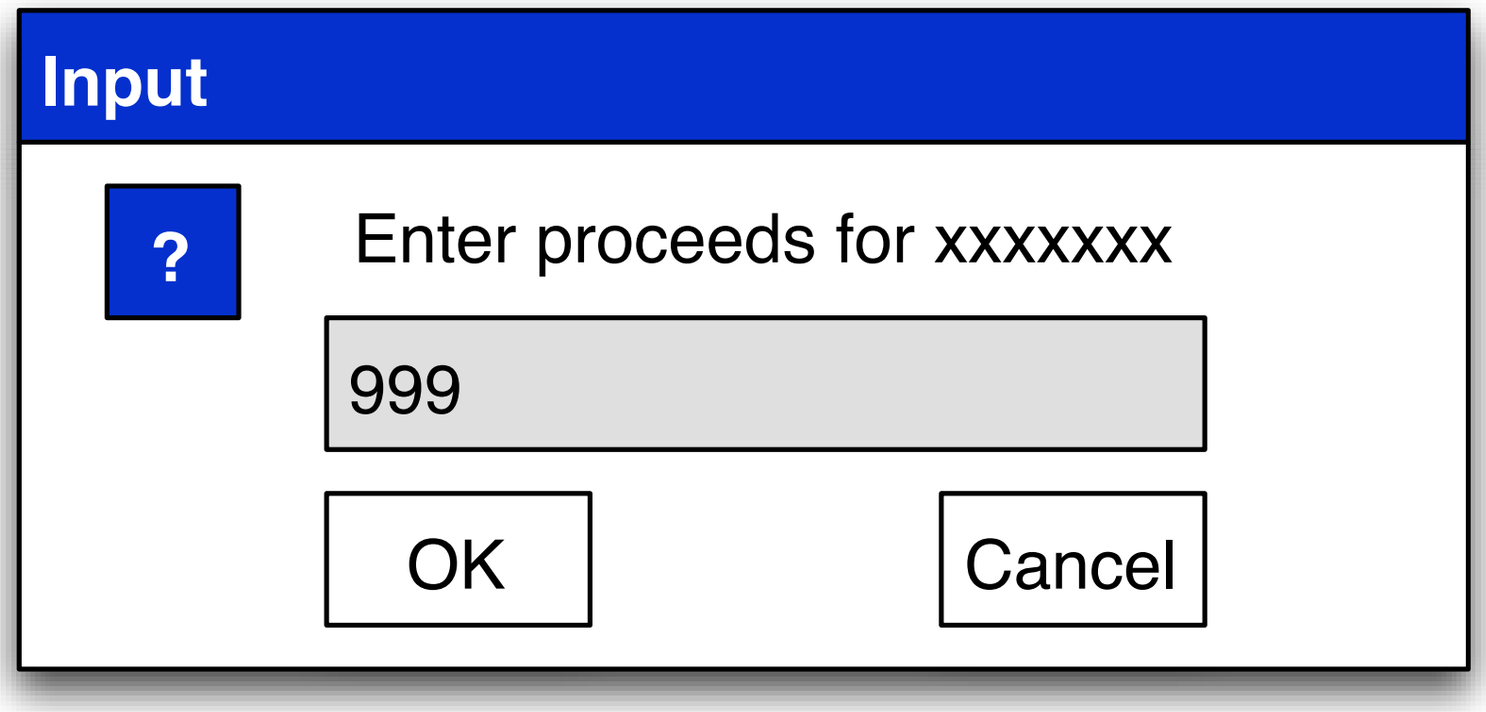
```
Type [] [] … [] identifier =
    new Type[DIM1][DIM2] … [DIMn];
```

- Where
  - `Type` is any known type
  - `identifier` is the handle for the array
  - each DIM_i is an expression that evaluates to a non negative integer

9.5 Graphical/Internet Java: A Pie-Chart Class

- Problem: Profit Analysis for Middle Earth Touring Company
- Program will prompt for proceeds on different tours
- Then display pie chart showing relative percentage of profit for each tour
- Program should be upgradeable for adding more tours in the future

Behavior



After entries are made for each tour destination, the program displays a window with a pie chart and legend with color codes and percentages for tour names

Operations for Pie-Chart Class

- Construct a pie chart given
  - String array with slice labels
  - double array containing raw values for slices
- Draw (paint) the chart
- Change color of given slice
- Change raw value of given slice
- We must also determine attributes for the program – window dimensions, etc.

`PieChartPanel` Constructor

- Receive as inputs
  - **`SLICE_LABELS`**, a constant **`String`** array
  - **`sliceValues`**, a **`double`** array
- Use a utility method **`computePercentages()`** to initialize attribute **`MySlicePercent`**

`paintComponent()` Method

- `Swing` components expect a method with this name
  - use `fillArc()` from the Graphics class
  - `fillRect()` to draw legend box
  - `drawString()` to label legend box
- Note the care taken to get arguments correct (location and size) for these methods
- Slices drawn by computing starting angle and size of angle based on %

Other Methods

- `setSliceColor()`
  - Receives slice number and new color
- `setSliceValue()`
  - receives slice number
  - new value
- Note full source code, Figure 9.14

Upgrading the Class

- Design of class enables ease of upgrading
- Only changes are including additional tour names in the TOURS array
- Note changes in Figure 9.15
- View output of sample run

Part of the Picture: Numerical Methods

- Application of Matrices: Solving linear systems

  $3x_1 + 4x_2 = 7$

  $4x_1 - 8x_2 = 12$

- Find the values (if any) for x_1 and x_2 that make the above pair of equations true statements
- Strategy used is called Gaussian elimination
- Manipulate the matrix to solve the system